STUDY OF MORTALITY OF ONTARIO MINERS

1955-1977

PART 1
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ONTARIO MINISTRY OF LABOUR
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ATOMIC ENERGY CONTROL BOARD OF CANADA

Ontario Ministry of Labour
Ontario Workers' Compensation Board
Atomic Energy Control Board of Canada

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1955-1977
PART I

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SUMMARY

A mortality study of Ontario Miners covering the period of 1955 to 1977 was carried out. There are 50,201 men in the study for a total of 754,391 person-years and 6,757 deaths were observed in this population over the period of the study.

The most serious hazard in this population was death due to violent causes. In men who worked full-time underground, there were 1,253 violent deaths observed over the study period as compared to 679.6 deaths expected. Nearly half the "additional" violent deaths occurred in uranium miners.

The population was subdivided into gold miners, nickel-copper miners, iron ore miners, other ore miners, mixed ore miners, and uranium miners. No complete exposure history was available on Ontario miners who also worked in the Eldorado Port Hope Plants or in Eldorado Mines in Saskatchewan or in the North West Territories. These men, therefore, were treated separately from the other miners as well as from men with known exposure to asbestos.

Only in certain types of miners was an increase in deaths from non-neoplastic lung disease detectable. No such increase was detectable in nickel-copper miners, in iron ore miners or in other ore miners. A significant increase was however noted in underground gold miners, mixed ore miners and in uranium miners. This increase was largely due to increased death rates from silicosis and chronic interstitial pneumonia. In gold miners and in mixed ore miners there were less than 10 deaths expected from this cause group but 179 were actually observed. In uranium miners about 2 deaths were expected from this cause group and 11 deaths were actually found.

In addition there were 43 deaths due to silicotuberculosis in gold miners and 36 deaths due to the same cause in mixed ore miners. It should be noted, however, that 71 of the 79 deaths due to this cause occurred prior to 1969 while 8 deaths occurred between 1969 and 1977 and only in the later period, the deaths occurred in men aged 65 years and older. It is estimated that the total difference between observed and expected deaths from silicosis and chronic interstitial pneumonia as well as from silicotuberculosis which was observed in gold miners and in mixed ore miners can actually be attributed to gold mining only.

Increased cancer risk in non-uranium miners was observed for cancer of the trachea, bronchus and lung in full-time underground gold miners and full-time underground mixed ore miners, and cancer of the stomach in full-time underground gold miners. No such increase was detectable in part-time underground gold or mixed ore miners. It is assumed that the increased risk of lung cancer in both these groups of miners is in fact due to underground gold mining only.

As to uranium miners, previous studies have already demonstrated an increased lung cancer risk in these men and this finding was confirmed in this study. Over the study period 1955 to 1977, 119 uranium miners died of lung cancer as compared to 65.8 deaths expected from this cause, giving a SMR of 181.

No increased mortality was detected in uranium mill workers for any group of causes except for violent deaths. Thirteen accidental deaths were observed as compared to 7.5 expected. It is worth noting that 6 of the 13 deaths were due to motor vehicle traffic accidents.

Men who have also worked for Eldorado Nuclear Limited show a significantly increased risk of death from all causes and from all disease causes. This is mainly due to a significant increase in the number of deaths from cancer of the trachea, bronchus and lung (33 deaths observed compared to 7.2 deaths expected, giving a SMR of 458) and to a significant increase in violent deaths (66 cases observed compared to 19.2 cases expected, giving a SMR of 344).

A first preliminary relative risk factor derived from Ontario Uranium Miners is given. This risk factor is to be refined in the second part of the study.

INTRODUCTION

A study of the health effects associated with employment in the mining industry should take into account the nature of that industry. The level of economic activity in the mining industry is largely dependent on the conditions of the market for the individual metals, and on factors which influence mining the ore. Some of these factors, such as the concentration of the metal in the ore and its depth under the surface change slowly. Market conditions, however, can change rapidly. As a result, those involved in mining - both companies and miners - have to adapt to these pressures. Miners frequently move from mine to mine, from mining camp to mining camp, and from mining one ore to mining a different ore as mining companies increase or slow down the rates of production. While gold mining represented the predominant mining operation in Ontario prior to and during the early years of World War II, it started to decline in the later years of the war, and continued to decline in the post-war years. As gold mining declined, the nickel and copper mining industry developed and employed an increasing number of miners. (See Fig 1).

Uranium mining started in Ontario in 1955, reached a peak in the late '50s and early '60s when an equally fast decline of production and employment set in. (See Fig 2 and 3). This restructuring of the mining industry obviously contributed to the high mobility of the Ontario mining population and should have an impact on the design of any study of the health effects associated with mining any ore.

In most mortality studies on miners, individual groups of miners (defined by the kind of ore mined or by an individual mining company) are studied in isolation. This was done in a pilot mortality study on Ontario uranium miners carried out by two of the present authors in 1974 (Mu74), similarly in a later study carried out by the Royal Commission on the Health and Safety of Workers in Mines (Ha76) and in studies on U.S. uranium miners (Lu71), Czech uranium miners (Se72, Se76, Ku78, Ku79) Swedish Miners (Jo73, Ax78), and others.

When studying the effect of a specific factor in the working environment on cause-specific mortality rates, for example the effects of exposure to short-lived radon daughter products in the mine atmosphere on lung cancer rates, a number of confounding factors have to

be considered. These certainly include age, smoking habits, and time since exposure. Most studies of this type attempt to take these confounding factors into account in one way or another. Other factors in the living environment (e.g. nutrition, living in Northern Ontario communities etc.) and in the working environment (e.g. dust, blasting fumes etc.) might also have to be recognized in assessing the risk in miners (Re78). This, perhaps, is less important when studying the effect of an environmental factor that is truly overwhelming, so that other possibly less potent environmental factors can be neglected. This study, however, concentrates on the effects of low doses of potentially cancer causing agents, and therefore contributions to risk from other factors in the working and living environment that might affect overall risk can no longer be neglected.

A demonstrated occupational risk in a given mine environment cannot simply be attributed to one single factor in the mining environment as is so frequently done. It is not unlikely that observed health effects are the result of the exposure to many physical and chemical agents not only in the present working environment of the miner but possibly also in his former working environment. This might well be in addition to extrinsic lifestyle factors that have already been mentioned. Various types of mines, such as gold mines, nickel-copper mines, and uranium mines, share a number of extrinsic and intrinsic factors related to mining, even though they might well differ in some others.

When investigating possible effects of exposure to a specific work environment, it is desirable to know the complete work history of the members of the study population. This, however, is only rarely possible. As miners generally change jobs within the mining profession, the study of the total industry, as opposed to the study of miners with a history of employment in one selected company or type of mine, is a useful step in this direction.

The present study constitutes an attempt to analyze the mortality pattern of various groups of miners in the context of the general mining population of Ontario rather than individual groups of miners in isolation as was done in previous studies.

MATERIALS USED

Development of the Work History File

An indication of the materials and methods used was presented previously (Mu81).

In this study a miner is defined as a person working at present or in the past, either full-time or part-time underground. In addition, however, a relatively small number of men with significant dust exposure on the surface was included in this group.

Pre-employment and yearly chest x-ray examinations were carried out by Ontario Government agencies for all miners since 1928. At this occasion, information about employment since the last examination was obtained.

In 1954 all information on men with radiological signs of silicosis or tuberculosis was coded and punched onto cards. In 1955, it was decided to supplement this file by adding data on men with 60 months or more of mining experience irrespective of their chest x-ray rating. This information was updated annually. In recent years all pertinent information was transferred to magnetic tape. The resulting file on magnetic tape was produced and maintained by the Ontario Workers' Compensation Board (WCB) and called the Mining Master File. This file contained information on about 80,000 men. The Mining Master File had serious shortcomings for the purpose of this study, however, and had to be modified. The shortcomings and modifications were:

1) Identifying information on men included in the file was incomplete. Only the first three letters of the surname were given; given names were not present on the file; the year of birth was indicated while the month and day of birth were not present. Social Insurance Number was never given. In creating the Work History File for this study, each miner's personal identifying data were updated. Full surname, with possible alternate names, both given names, as well as the full date and place of birth, and Social Insurance Number, whenever available, were entered.
2) The Mining Master File contained only the employment information which was obtained during examinations that were carried out after qualifying for inclusion into the Mining Master File. As a result, limited information on employment for the first five or more years

of mining was available on the file. Employment information during the first five years of employment in the mining industry was retrieved from work history cards and entered into the Work History File.

3) The data on the Mining Master File were insufficient for assigning radiation exposure to individual uranium miners in a given calendar year. Exposure data for uranium miners were, therefore, "calendarized". This means that individual months of work underground and consequently exposure to radon daughters were assigned to a specific calendar year. For this purpose it was necessary to know as accurately as possible the number of months a man worked in each mine and occupation between successive examinations. In the Mining Master File, however, only the one mine and occupation in which the miner spent "most of the time" between two examinations was recorded. Surface employment and periods of unemployment were not on the computer file. Details of individual employments were recorded in the new file and properly sequenced. A total of 122,200 enhancements of this type had to be carried out to the Uranium miners' file in addition to the enhancement of the file of non-uranium miners mentioned previously. Recalendarization of the exposure data was done each time additional enhancements of employment records were carried out.

The Study Population

The study population consists of four major groups:

a) Uranium miners: These are men who worked one-half month or more in an Ontario uranium mine between January 1, 1955 and December 31, 1977. This cohort consists of 17,102 men. For the purpose of this report men with known asbestos exposure and men with exposure in Eldorado mines or plants have been put into separate groups. This reduces the present cohort of uranium miners to 15,984 men. Out of the 15,984 men, 10,541 had some hardrock mining experience prior to starting uranium mining and 5,443 men had no prior hardrock mining experience.

b) Non-uranium miners: These are men with 60 months or more of mining experience including one-half month or more of mining experience in an Ontario mine so long as they do not qualify as uranium miners.

Some men qualify as non-uranium miners first and become uranium miners later in the study. An additional condition is that they are known to have been alive at some time between January 1, 1955 and December 31, 1977. A total of 33,099 miners fulfilled the conditions for inclusion in the study population as non-uranium miners. After exclusion of men with known asbestos exposure or employment in an Eldorado uranium mine or plant, this number was reduced to 31,895 men.

c) Asbestos Workers: These are men who have ever worked in an asbestos mine or who have any known asbestos exposure. A total of 928 men fit this definition. Four hundred and twenty-one would otherwise have qualified as uranium miners and 507 as non-uranium miners.

d) Eldorado Miners: It was assumed that some Ontario miners might have had some exposure in Eldorado uranium mines or mills in Saskatchewan or the North West Territories or in the Eldorado uranium refinery in Port Hope. The file of Ontario miners was, therefore, compared in Statistics Canada with a file of present and former Eldorado employees using a file linkage procedure described below. A total of 1,430 men were identified as being on both files. Seven hundred and twenty-six of these men would otherwise have qualified as Uranium Miners as defined above and 704 as non-uranium miners. We have at present no information on the exposure of these men to radon and its short-lived daughters or to other possible internal emitters or external gamma radiation while working for Eldorado. For this reason it was decided to treat these men separately in Part 1 of the study. They can be included in the later stages of work when exposure data from Eldorado become available.

There were 36 men included in both asbestos workers and Eldorado miners.

THE DEATH SEARCH

A death search of the total study population of miners was carried out for the years 1955 to 1977.

The "nominal roll" of miners in the study was supplied to Statistics Canada. This data file contained: full surname, any recorded variations of the surname, first given name, second given name,

and birth information including year, month and day of birth, and place of birth. In about 50% of the men, the Social Insurance Number was known and also supplied as part of the identifying information. Social Insurance Numbers were used by Statistics Canada to identify variations in the identifying information in the nominal roll and to obtain the mother's maiden name, a very powerful personal identifier. This was achieved by matching the Social Insurance Numbers in the nominal roll and the Unemployment Insurance files. The year of the last recorded mining examination was used as the year when the man was last known to be alive. This nominal roll included 50,201 men and was linked by computer with the Canadian Mortality Data Base (MDB) maintained by Statistics Canada. In the absence of unique identifiers, both on the MDB and on the nominal roll submitted for linkage, Statistics Canada has developed computer techniques which utilize agreement or disagreement among variables contained in both files to calculate the weight carried by a link between an entry in the MDB and the nominal roll. The calculated weight of the link is related to the probability that the data on both files refer to the same individual. In order to allow for spelling variations in a person's surname, a phonetic New York State Identification Intelligence System (NYSIIS) surname code was used (Ly77). For details of the linkage procedure see Sm80a, Sm80b, Sm80c, Sm81a, Sm81b, and Sm81c. The NYSIIS code of the surname was used as a primary identifier. If the variations in spelling of the surname were such that the NYSIIS codes on the nominal roll and on the MDB were different, the fact of death was not determined. The linkage procedure was carried out by M. E. Smith and P. L. Lalonde of Statistics Canada.

A detailed examination was made of a sample of links having weights above 170. Based on the results of this examination, a minimum weight of 200 was selected as the criterion for accepting a link. The lower this minimum is set, the more false links there are and the fraction of true matches rapidly diminishes. Based on the analysis of the sample mentioned, it was decided that the minimum weight of 200 is, for the purpose of this study, a reasonable compromise between deficiencies of identifying deaths and the great loss of time and loss of quality of work involved in manually processing a large number of false links.

Manual resolution of links was carried out by considering data on the death certificate and in files at the WCB that could not be taken

into account when assigning a weight to a link by the file linkage procedure. Day and month of birth were usually not available on the MDB for Ontario in the early years of the search. These data, however, were available on the death certificate and on the WCB files. Agreement or disagreement in these data served as a useful guide. Also the occupation of the deceased was not coded in the MDB, but useful information was found frequently on the death certificate. File linkage procedures can be improved when information not used by the computer is considered. Such information was frequently available on other files and was used in the manual resolution.

Based on the manual resolution, 11,883 links were grouped into four categories: a) true match b) probable match c) possible match d) no match.

For the purpose of the study only links that were a) true match or b) probable match were considered acceptable, and links that were considered, c) possible match or d) no match were excluded. Out of a total of 11,883 links 6,757 were accepted as true and probable matches and 5,126 links were rejected. This indicates that even at a minimum weight of 200, a considerable number of links had to be rejected by manual resolution. Further decreasing the acceptable weight for an acceptable link would greatly increase the number of links that would have to be rejected by manual resolution.

It was considered advisable to test the efficiency of the death search on a sample of men whose deaths were considered to be known prior to making the death search. For this purpose a list of International Nickel Company (INCO) employees who had been the recipients of a company pension and were known to have died subsequently has been obtained* and subsequently matched by hand with the nominal roll. A total of 1,097 men were found to be on both the lists. Positive links with the MDB had been received on 1,028 (94%) of the deceased but there were no positive

* Courtesy J.A. Julian, McMaster University

links in 69 cases (6%). The most important reasons for failing to identify the deaths were:

a)	Miner Died Outside Canada	27 cases	- 2.5%
b)	Insufficient Weight	22 cases	- 2.0%
c)	NYSIIS Code Different	12 cases	- 1.1%
d)	Miners Still Alive	1 case	- 0.1%
e)	Other Reasons	7 cases	- 0.6%
	Total	69 cases	- 6.3%

Lowering the lower limit of weight from 200 to 130 would decrease the number of cases missed for insufficient weight from 22 cases to 12 cases (from 2% to 1.1%) and the total fraction of unidentified deaths would be lowered from 6.3% to 5.2%. The total number of links to be considered would have increased dramatically. The potential gain was not considered sufficiently cost-effective considering the much increased cost and effort of manual resolution. Even setting the lower weight limit at 200, giving a total of 11,883 acceptable links, a significant proportion of 43% proved not acceptable as true matches on manual resolution.

An effort was made to identify and eliminate all duplicate entries in the file by manual cross-referencing. Later an internal computerized file linkage procedure was also used in Statistics Canada to identify duplicate entries of the same individual in the file. The number of possible duplicates found was sufficiently small so that inclusion of true duplicates would not greatly affect the results of the study.

SUBDIVISION OF NON-URANIUM MINERS

It was felt that there might well be differences in risk according to the type of ore mined, apart from the obvious differences in exposure to radioactive substances between uranium miners and non-uranium miners. These differences might well be related to differences in the geology of the rock formation associated with the ore. In the circumstances of mining in Ontario, it appeared reasonable to group miners into a) gold miners, b) nickel-copper miners, c) iron ore miners, d) other ore miners, and e) mixed miners.

It would have been ideal to designate a miner to an individual ore if he had never worked in any other ore in Ontario and if he had never worked outside Ontario. Another possibility would have been to count men more than once if they worked in more than one ore. A man would then be included, for example, among gold miners, even though he might have worked only a few months in a gold mine but had many years of exposure in a nickel mine or vice versa. A compromise solution was therefore sought that would not limit unduly the number of men assigned to an individual ore, but would still prevent excessive blurring of the distinction between men grouped under one ore from men grouped under another ore. After exclusion of asbestos miners and former Eldorado employees, non-uranium miners, were, therefore, for the purpose of this study subdivided into five sub-groups using the following rules:

a) A gold miner is a non-uranium miner who has spent 85% or more of his total mining experience, in and outside Ontario, in an Ontario gold mine.

b) A nickel-copper miner is a non-uranium miner who has spent 85% or more of his total mining experience, in and outside Ontario, in an Ontario nickel-copper mine.

c) An iron ore miner is a non-uranium miner who has spent 85% or more of his total mining experience, in and outside Ontario, in an Ontario iron ore mine.

d) An "other ore miner" is a non-uranium miner who has spent 85% or more of his total mining experience, in and outside Ontario, in Ontario mines other than gold, nickel-copper or iron.

e) A "mixed ore miner" is a non-uranium miner who does not fit any of the above definitions.

It should be noted that at one time a miner may be classified as a non-uranium miner, and he may qualify as a uranium miner later. Once a man is an uranium miner, however, he never can qualify as a non-uranium miner.

The miners were further classified into full-time underground miners and part-time underground miners such as electricians, maintenance workers, etc. A man was assigned to one or the other sub-group according to the proportion of his time employed as part-time or full-time underground miner. He was assigned to the sub-group in which he spent more than half of his total exposure time.

In addition to non-uranium miners there are 15,984 uranium miners included in the study. These include both full-time and part-time underground workers as well as certain categories of surface workers, e.g. mill workers.

EXPOSURE DATA FOR INDIVIDUAL MINERS

Pilot studies carried out previously give an indication that there is an increased lung cancer risk in former Ontario uranium miners (Mu74, Ha76). The exposure of the Ontario uranium miners was relatively smaller than uranium miners studied elsewhere. Less extrapolation to the low doses of interest is therefore needed than from data obtained on U.S. and Czech uranium miners. An important characteristic of Ontario miners is the relatively short period of exposure in the late fifties and early sixties which may simplify the study of latency. These were important considerations in deciding to study the relationship between exposure and lung cancer risk in quantitative terms.

No comparable mortality studies on Ontario non-uranium miners had been published when this study was initiated. The results of the recent studies on nickel miners (Ro82, Sh82) did not indicate that a mortality study aimed at establishing the quantitative relationship between exposure to various environmental factors and death from occupational disease would serve a useful purpose. The silicosis risk in gold and uranium miners is well known. The dynamics of the development of this disease in relation to exposure can, in the authors' opinion, be better studied in a morbidity study than in a mortality study. It was, therefore, felt that a mortality study neglecting at first the quantitative aspects of exposure to various agents in the non-uranium mine environment was justified. No assessment, in quantitative terms, was, therefore, made of the exposure of non-uranium miners to various dusts in the mine environment.

For these reasons, an attempt was made to evaluate exposure to short-lived daughter products of radon-222 in uranium miners, and no attempt was made at this stage of the study to evaluate exposure to silica or other non-radioactive dusts in uranium or non-uranium miners.

Information on radon daughter exposure in uranium miners is based

on area monitoring only. For the period 1955 to 1967 the exposure of each miner for each calendar year was calculated using the Working Level Table (See Table 1). For the period 1968 and later, personal exposure data were available.

There are uncertainties in hitherto accepted values for concentrations of radon daughters in the mine air for the early years of uranium mining in Ontario. A small group of mining engineers* who were familiar with the Ontario uranium mines over the early years of operation was consulted on the appropriateness of the values used. There was a consensus of opinion that in many cases, values of radon daughter concentrations in mines for the first years of mining were underestimated. The accepted values of radon daughter concentrations in mines were, therefore, used as lower bounds of the true concentrations. The engineers also suggested upper bounds for the weighted concentrations of short-lived daughter products of Radon-222 in the mine air. The values of Standard Working Level Mine (Std. W.L. Mine) and the Special Working Level Mine (Spec. W.L. Mine) given in Table 1 are the lower and upper bounds of the weighted concentration of short-lived daughter products of radon-222 in the mine air expressed in units of Working Level (WL).** Weighting is based on the assumption that the miner spends 80% of his time underground in stopes and raises and 20% in travelways. The Standard Working Level contractor values (Std. W.L. Cont.) apply to work of contractors employed in shaft sinking and other non-production work. The work history factor (W.H.F.) corrects for deviation from normal working hours in a mine. A W.H.F. of 1 indicates that normal working hours apply in a mine. A W.H.F. greater than 1 indicates overtime work and a W.H.F. less than 1 indicates work stoppages.

For the period 1955 to 1967, the number of WLM*** a man was exposed to in any given calendar year was determined as the sum of the products of months worked in each mine in the calendar year with W.H.F. and with

* The authors wish to express their thanks to Messrs. R. Yourt, W. Bardswich and J.L. Chakravati for their help in this matter.

** 1 WL corresponds to 1.3×10^5 MeV of potential alpha energy per litre of air.

*** 1 Working Level Month (1 WLM) corresponds to the exposure to 1 WL for one working month (170 hours).

W.L. Mine. The calculation was carried out using both Std. W.L. Mine and Spec. W.L. Mine values, thus obtaining bounds for exposure. It was assumed that part-time underground miners (e.g. electricians, maintenance workers, etc.) spent 50% of their working time underground.

For 1968 and later, personal exposure data were used. These were derived by multiplying the number of hours a man spent in each location underground by the concentration of radon daughters (WL) in the same location and adding the WL-hours over the calendar year. These were then converted into WLM.

SOME DESCRIPTIVE DATA ON THE STUDY COHORTS ACCORDING TO ORE MINED

Taking into account the history of mining in Ontario and the various shifts in employment of miners mentioned earlier, major differences were expected to be found in certain demographic characteristics in various groups of the study population.

Gold miners, nickel-copper miners, iron ore miners, other ore miners, mixed ore miners and uranium miners were compared for a number of parameters: Fig. 4 gives the cumulative distribution of years of birth by ore mined. As can be seen from the graph, gold miners were born earlier than other hard rock miners, and uranium miners were the youngest. It is not surprising to find that gold miners also started mining in Ontario earlier than other miners (see Fig. 5). It is, however, striking to see that the number of years spent mining by gold miners and nickel-copper miners was very similar (see Fig. 6). Gold miners started mining generally earlier than did nickel-copper miners and also left the mines earlier. More than 10% of the nickel-copper miners and more than 15% of gold miners included in the study, worked in their respective ore for more than 30 years. The number of years mined by other miners is much shorter. It is worth noting than 87% of the uranium miners had less than 5 years of uranium mining experience. Most uranium miners - 10,541 out of 15,984 (66%) had previous mining experience but only 3,044 met the conditions stated previously for inclusion in the study as non-uranium miners prior to starting uranium mining.

Fig. 7 gives the distribution of year of entry into the study by ore mined. Gold mining is an old established industry where employment was decreasing for a number of years prior to 1955 when the study starts. The rate of hiring new employees in the period 1955 to 1977 was low. As a result, a very significant proportion (57%) of gold miners already qualified for inclusion in the study in 1955.

The opposite is true for uranium miners who were entering a new, rapidly developing industry in 1955. As only 0.5 months of uranium mining was required for inclusion in the study, men qualified quickly after they were hired and by 1960 more than 70% of all uranium miners included in the study had qualified. The rate at which new uranium miners qualified for inclusion in the study rapidly decreased after only 5 years (1960) and only about 30% of the total uranium miners population qualified for inclusion into the study between 1961 and 1977. The fact that most men entered the study in the early years of uranium mining and worked for a short period only (median = 1.5 years) might be significant for the study of latency of radiation induced lung cancer.

Person-Years at Risk (PYR) were calculated for non-uranium miners from the time of qualification in the study up to the start of uranium mining, until death or up to the end of 1977, whichever occurred first.

In uranium miners, PYR were calculated from the time of qualification as uranium miners until death or up to the end of 1977, whichever occurred earlier. Fig. 8 indicates the proportion of PYR in the study by age. As expected from data shown earlier, the follow-up period or PYR covers an older population in gold miners and a very young population in uranium miners. The distribution of PYR by age of nickel-copper miners, iron ore miners, other ore miners and mixed ore miners is between that for gold miners and that for uranium miners.

Table 2 indicates the number of men, Person-Years at Risk and mean Person-Years at Risk for full-time and part-time non-uranium miners by ore mined, as well as for uranium miners, asbestos workers, Eldorado workers, and Eldorado workers who also had asbestos exposure.

Taking into account both the age distribution of the Person-Years at Risk and also the average number of Person-Years at Risk per man, it is not surprising to find that 28.8% of gold miners died during the course of the study and only 8.2% of uranium miners. As far as miners

other than gold and uranium miners are concerned, the percentage of men who died during the course of the study was: 11.8% of nickel-copper miners, 7.6% of iron ore miners, 9.8% of other ore miners and 16.3% in mixed ore miners.

Table 3 gives the median values for parameters presented graphically in Fig. 4 to 8.

Table 4 gives the percentage of PYR above the age of 40 by ore mined.

As lung cancer is a relatively rare disease at ages below 40 years, and the age-specific death rate rapidly increases in higher age groups, a substantial rise can be expected in the number of lung cancer cases derived from the uranium miners cohort in future years, followed by a decrease as a result of the decreasing population at risk. This increase in the number of cases occurring per year would appear independently of radiation exposure. The peak lung cancer incidence in the study population can be expected around the year 2000. In later years the number of new cases per year will diminish as the study population at risk diminishes. (See Fig. 9).

Descriptive Data On The Gold Miners Cohort According To Mining Camp

It was recognized that there might well be historical, sociological and other differences among miners mining the same metal in different mining camps. There might also be differences in the geology of mines located in the various geographic locations.

While nickel-copper miners were generally concentrated in the Sudbury area, the 6,972 full-time underground gold miners are distributed in three major camps:

Timmins	3,796 men
Kirkland Lake	1,770
Fort William	890
Other Camps	130
Mixed Camps	386
Total	6,972 men

Timmins gold miners were somewhat older than Kirkland Lake miners and gold miners in other mining camps (see Fig. 10). They started

mining in Ontario earlier (see Fig. 11). They had more years of gold mining experience than Kirkland Lake miners and gold miners in other mining camps (see Fig. 12). They entered the study somewhat earlier than Kirkland Lake miners but substantially earlier than gold miners from other mining camps (see Fig. 13). Timmins miners also contributed relatively more Person-Years at Risk in older age groups than miners from other mining camps (see Fig. 14).

All these differences were, however, not as large as between gold miners and men mining other ores. Table 5 gives median values for the parameters whose distributions were graphically presented in Fig. 10 to 14.

Descriptive Data on Cohort of Uranium Miners by Mining Camp

There were a total of 15,984 uranium miners with no known asbestos exposure and no work history in Eldorado mines or plants included in the study. Most of the men worked in the two major mining camps, Elliot Lake or Bancroft, for 85% or more of their total uranium mining experience. These men are considered Bancroft miners or Elliot Lake miners respectively. Some of the men, however, spent less than 85% of their total uranium mining experience in either of the two camps and these men are considered mixed uranium miners. Some of the men had non-uranium mining experience prior to starting uranium mining and others did not. Table 6 indicates the number of men by mining camp and previous non-uranium mining experience.

Bancroft miners were born somewhat earlier than Elliot Lake miners (see Fig. 15). There is no great difference between Bancroft and Elliot Lake miners as to the years of starting mining in Ontario, but miners having mixed uranium mining exposure started mining in Ontario somewhat earlier (see Fig. 16). Elliot Lake miners tend to have mined somewhat longer than Bancroft miners (see Fig. 17), but Bancroft miners qualified for entry into the study generally earlier than Elliot Lake miners (see Fig. 18). There does not appear to be a major difference as to the distribution of Person-Years at Risk by age in the two mining camps (see Fig. 19), but the median age of Elliot Lake miners during the study period was somewhat lower than that of the Bancroft miners. Table 7 gives median values for the parameters whose distribution was

graphically presented in Fig. 15 to 19.

RESULTS

MORTALITY DATA FOR SUB-GROUPS OF THE MINING POPULATION

For the purpose of this study causes of death were accepted as coded on the death certificate. No attempt was made to re-evaluate this coding, as recoding might affect comparability with the Ontario male population. For the period 1955 to 1968 the Seventh Revision of the ICD codes was used and for the period 1969 to 1978 the Eighth Revision was used. Causes of death were grouped in this report, but more detailed rates are available if needed.

Table 8 indicates the individual ICD codes of the Seventh and Eighth Revision included in the individual death cause groups. The same death cause groups are used throughout the study.

In all the tables of mortality data, the expected number of deaths were calculated using age and calendar period specific mortality rates for the male population of Ontario. The p-values shown are for a one-sided test of the hypothesis that there is no increase in risk for the particular sub-group of the study population. The p-value appears only when it is at most 0.05 (5E-02).

Tables 9 to 14 give the number of expected and observed deaths as well as Standardized Mortality Ratio (SMR) for the varous death cause groups for Nickel-copper miners (Table 9), Gold miners (Table 10), Iron ore miners (Table 11), Other ore miners (Table 12), Mixed ore miners (Table 13), and Uranium miners (Table 14).

Underground Nickel-Copper Miners:

In underground nickel-copper miners, a total of 1,444.6 deaths were expected and 1,341 observed, giving a SMR of 93. This "deficit" of observed deaths is likely largely due to a "healthy worker effect". This difference in expected and observed deaths is still more marked in disease causes of deaths where 1,277.0 were expected and 1,108 deaths observed, giving a SMR of 87. No increase in cancers of the respiratory system or non-specific lung disease could be demonstrated in this group of miners. There were 16 deaths of cancer of the prostate observed

against 14.0 deaths expected, giving a SMR of 115. This increase was not significant at the 5% level.

The most important increase in the number of observed deaths as compared to the number of expected based on Ontario population data is for accidents, poisoning, and violent deaths, where 233 cases were observed compared to 167.6 expected, giving a SMR of 139. A notable increase in violent deaths is in those due to a blow from falling or projected missiles where 4.2 cases were expected compared to 30 cases observed, giving a SMR of 708. (See Table 9)

Underground Gold Miners:

Table 10 gives the observed and expected number of deaths as well as the SMR for underground gold miners. Again there is a smaller than expected number of deaths from all causes and also from all disease causes. This is believed to be due to a healthy worker effect.

However a marked increase is found in deaths from infective diseases compared to the number of deaths expected, giving a SMR of 364. This is mainly due to a large number of deaths due to silicotuberculosis. Forty-one deaths from this cause were observed in this group of miners. It might be worth noting that 60 deaths of stomach cancer were observed as compared to 40.4 deaths expected, giving a SMR of 148, while 65.4 deaths of cancer of the intestine and rectum were expected and 28 deaths were observed.

The most striking feature in the mortality data for underground gold miners is, however, a marked increase in respiratory cancers and other diseases of the respiratory system. The significant increase in cancers of the respiratory system is due to a marked increase in deaths from cancers of the trachea, bronchus and lung. While 134.9 deaths from this cause were expected, 196 deaths were observed giving a SMR of 145. Similarly the marked excess of deaths from diseases of the respiratory system was largely due to a substantial increase in deaths from silicosis and chronic interstitial pneumonia where 6.6 cases were expected and 111 observed, giving a SMR of 1,688.

Deaths from accidents, poisoning, and violence also showed a marked increase in this group of miners. The number of deaths from motor vehicle traffic accidents shows no marked increase whereas other violent

deaths, particularly deaths from blows from falling or projected missiles, a typical mining accident, show a highly significant increase. Forty-nine deaths from this cause were observed but 2.8 deaths were expected, giving a SMR of 1728. Similarly fatal accidents due to firearms or explosives, other vehicle accidents, water transport accidents and "all other accidents" showed a marked increase.

Iron Ore Miners:

Iron ore miners working in full-time dust exposure showed no significant difference between expected and observed deaths by cause. Where 40.8 deaths from all causes were expected only 35 cases were observed, giving a SMR of 86. This ratio is not significantly different from a ratio of 100. A possible deficit in observed deaths is likely due to the healthy worker effect. No individual cause of death shows a significant excess of observed cases over the number expected. (See Table 11).

"Other Ore" Underground Miners:

For other ore underground miners, only a healthy worker effect could be demonstrated. (See Table 12).

"Mixed Ore" Underground Miners:

Mixed ore underground miners (see Table 13) show a pattern of mortality similar to gold miners. There are 35 deaths due to silicotuberculosis. In addition, there were 101 deaths from cancer of the trachea, bronchus and lung where 69.5 deaths were expected. Also, there is a significant excess of diseases of the respiratory system, particularly 68 deaths from silicosis and chronic interstitial pneumonia where 3.2 deaths were expected. Accidental falls, blows from falling or projected missiles, firearms or explosives, as well as other accidents show the pattern similar to other Ontario miners. There is, however, a significant increase in motor vehicle traffic accidents which might possibly be indicative of certain lifestyle patterns.

Salt Miners:

A nominal roll of employees of the Canadian Rock Salt Company was collected to evaluate the lung cancer risk in miners exposed to diesel fumes and little else in the work place. Person-Years at Risk were calculated from September 1, 1955 or five years after the start of employment, whichever occurred later, to the end of 1977 or the time of death, whichever occurred earlier. Eighty-two full-time underground miners and 97 part-time underground miners were included in this study. Five part-time underground miners died during the period of this study as compared to 7.5 expected and 8 full-time underground miners died as compared to 6.3 expected. The small size of the population considered as well as the short follow-up period do not allow any valid conclusions to be drawn from this part of the study.

Uranium Miners:

Uranium miners (Table 14) show a significant increase in deaths from all causes. While 1,113.8 deaths from all causes were expected, 1,316 deaths were actually observed, giving a SMR of 118. The increased number of deaths is largely due to a significant increase in violent deaths; 819 deaths from all disease causes occurred and 890.9 cases expected. There were significantly more deaths from malignant neoplasms, 259 observed, compared to 222.2 expected. This excess is due to a significant increase in cancers of trachea, bronchus and lung, where 119 deaths were observed as compared to 65.8 expected, giving a SMR of 181. A significant increase in the number of deaths was observed for silicosis and chronic interstitial pneumonia, 11 cases were observed where 2.1 cases were expected, giving a SMR of 514.

There were 497 deaths due to accidents, poisonings and violence while only 222.8 cases were expected. This excess of observed cases is due to a substantial increase in motor vehicle traffic accidents, water transport accidents, accidental falls, blows from falling or projected missiles, firearms or explosives, other vehicle accidents, and all other accidents. Some of these accidents are obviously work related, such as death due to blows from falling or projected missiles, while other types of accident, such as motor vehicle traffic accidents are more related to lifestyle factors.

Within the uranium miners group, mill workers constitute a sub-group of special interest. There were 567 men who ever worked in a mill, "ever mill workers", and only 115 of them never worked underground in a uranium mine, "ever mill and never underground". The ever mill and never underground uranium workers were observed for a total of 1,457 person-years. A total of 8 deaths was observed in this group of men over the study period (see Table 15) and no significant difference between observed and expected numbers of deaths was detected for deaths from all causes or for any of the major cause groups.

In order to increase the number of men and person-years, mill workers were also investigated, including those with underground uranium mining exerience in Ontario. The ever mill workers were observed for a total of 8,054 person-years. No significant increase in mortality from all causes or any specific cause group could be detected except for accidents, poisoning and violence (See Table 16). This increase was largely due to a significant increase of deaths from motor vehicle traffic accidents.

"Part-time Underground" Non-Uranium Miners:

In "part-time underground" non-uranium miners there was no significant increase of observed deaths compared to expected deaths in any of the ore groups and any of the major cause groups (See Tables 9a to 13a) except two cases of silicotuberculosis that occurred in part-time underground gold miners (See Table 10a). This tends to support the view that the excess lung cancer risk in underground gold miners is most likely work related.

MINERS GROUPED BY MINING CAMP

Underground Gold Miners:

No evidence is available at present linking the observed increased lung cancer risk in underground gold miners to any specific occupational factor in these mines. It was therefore of interest to investigate if gold mining in the various mining camps constituted a comparable risk. As shown previously (see Figures 10 to 14) there are differences in demographic data in gold miners from various mining camps. In addition,

it was considered not unlikely that there might also be certain differences in the geology of the mines in the various camps. Gold miners were, therefore, divided into sub-groups by mining camp as indicated previously and their mortality data were analyzed. (See Tables 17 to 21).

Underground Timmins gold miners show the same general picture as all underground gold miners. A substantial number of deaths occurred due to silicotuberculosis. There is a somewhat increased number of stomach cancer deaths. Death rates from cancer of the trachea, bronchus and lung are significantly increased as well as deaths from silicosis and chronic interstitial pneumonia. Also violent deaths show the pattern observed in other mining groups (See Table 17). Kirkland Lake underground gold miners show a pattern similar to Timmins miners. There is a substantial number of deaths due to silicotuberculosis, silicosis and chronic interstitial pneumonia. For cancer of the trachea, bronchus and lung the increase in the observed number is of borderline significance, and less marked than in Timmins miners. The difference between lung cancer rates in Timmins miners and Kirkland Lake miners is, however, not statistically significant. Violent deaths show a pattern similar to other mining groups. (See Table 18). Underground miners in the Fort William mining camp show two deaths from silicotuberculosis, a significant increase in deaths from cancer of the trachea, bronchus, and lung and also the number of deaths from silicosis and chronic interstitial pneumonia is significantly higher than expected. The pattern of mortality in Fort William is more comparable to that in Timmins than to the mortality pattern observed in other gold mining camps (See Table 19). In this context it should be noted that miners in the Fort William mining camp were generally younger than those in other mining camps, started mining later than other gold miners and spent fewer years in gold mines than miners in other gold mining camps. The similarity of the findings to those in Timmins miners is, therefore, of special interest.

Underground gold miners in other camps or in mixed camps show no significant increase in lung cancer deaths. Significantly more deaths than expected are observed from silicotuberculosis and from silicosis and chronic interstitial pneumonia (See Tables 20 and 21).

Uranium Miners:

Comparing the Elliot Lake and Bancroft uranium mining camps (see Tables 22 and 23), there were in both instances a greater number of deaths than expected based on the Ontario male population. This increase is largely due to an increase in violent deaths in both mining camps. There were no deaths from silicotuberculosis in either of the mining camps. In both mining camps there was a signficant increase in the number of deaths from cancer of the trachea, bronchus and lung. In the Bancroft mining camp 12.4 deaths from lung cancer were expected and 30 deaths were observed, giving an SMR of 241. In the Elliot Lake mining camp 50.0 lung cancer deaths were expected and 81 lung cancer deaths were observed, giving an SMR of 162. This increase was highly statistically significant in both mining camps. The most striking feature in both mining camps is the great number of deaths from accidents, poisoning and violence; 79 deaths in the Bancroft mining camp were observed, while 36.2 were expected giving an SMR of 218; 388 deaths were observed in Elliot Lake while 175.5 deaths were expected, giving an SMR of 221. Both, typical mining accidents, such as blows from falling or projected missiles and non-mining accidents such as motor vehicle traffic accidents are significantly increased in both mining camps.

Eldorado and Asbestos Workers:

Table 24 indicates mortality data relating to members of the study population who have never been involved in asbestos mining and who were successfully linked with members of the Eldorado nominal roll. No effort was made at this stage to eliminate possible spurious links. As a result some men with no Eldorado experience have been included in this group. Nevertheless, it is noteworthy that the lung cancer risk in this group is very high. There were 33 deaths from cancer of the trachea, bronchus and lung observed when only 7.2 deaths were expected, giving a SMR of 458. Most of these lung cancer deaths (25 out of the 33 deaths) occurred in men who never mined uranium in Ontario. Inclusion of former Eldorado workers within the study population would have affected the results of the study, particularly with respect to non-uranium miners.

Table 25 gives the number of observed and expected deaths by cause and the respective values of the SMR for former asbestos miners who have

never worked in Eldorado. As can be seen from Table 25, inclusion of this group of miners within the study population would probably not have significantly affected the results of this study.

In addition, there were 36 men who were both former Eldorado workers and asbestos miners. Five deaths occurred in this group and none was due to cancer.

Table 26 gives a first approximation to the evaluation of risk factors for radon daughters. This is a very crude result which will be refined in Part 2 of the study.

DISCUSSION

The present study constitutes an attempt to analyze the mortality pattern of various groups of miners in the context of the general mining population of Ontario, rather than individual groups of miners in isolation, as was done in previous studies. This approach made it possible to use the definition of the various groups of miners, taking into account the total mining experience of each miner, rather than looking at the experience in mines belonging to one company only, or in one ore, or one mining camp. In addition, men who had previously worked in the uranium industry outside the province of Ontario were identified and treated separately. Both of these procedures were of assistance in separating the risk resulting from exposures in different types of mines and occupations.

In many instances, mixed employments occur such as gold mining and uranium mining or gold mining and nickel-copper mining, and a good knowledge of every man's <u>total</u> employment history in whatever Ontario mine is very helpful in assigning risk to the individual occupation.

In most cohort mortality studies on industrial populations using general population data as a standard for comparison, fewer deaths from the various causes are observed than are expected. As a result of the healthy worker effect, mortality rates in industrial populations usually range from 60% to 90% of that in the general population (Pa77). A healthy worker effect was observed in all groups of Ontario miners for most of the causes of death. Fewer deaths were actually observed than expected based on the Ontario population. This might well be partly due to self-selection of healthy men into mining. In addition, men were

actively working at the time of entering the study and, therefore, not seriously ill at that time. This "deficit of deaths" is rather striking in diseases of the circulatory system in underground gold miners.

In all the major underground mining groups a substantial increase is found in violent deaths, compared to Ontario males. Such an increased risk is usually encountered in heavy industries and particularly in underground mining. Table 27 gives the number of observed and expected violent deaths and SMR values for the various groups of Ontario underground miners. Data on Colorado Uranium miners are given for comparison (Wa81).

The relative risk of violent death appears to be higher in uranium miners than gold miners or nickel-copper miners. Gold miners and nickel-copper miners entered the study after five years or more of dust exposure in mines, while only 0.5 months of uranium mining was required for qualifying as uranium miners for this study. It is not unlikely that the risk of violent death was greater for the first five years in nickel-copper or gold mining than for later years of mining and this, as well as differences in the age composition of the various groups, might well account for the differences in risk of violent death between gold miners and nickel-copper miners on one hand and uranium miners on the other hand.

This study did not address itself specifically to a detailed analysis of violent deaths. It is however felt that a significant proportion of these deaths is preventable by appropriate actions in the workplace and by programs aimed at influencing the lifestyle of miners. A very high priority should be given to a detailed study and to remedial action aimed at the prevention of violent deaths both in and outside the workplace.

A far more detailed discussion of accidents and injuries in the Ontario mining industry can be found in the Ham Commission Report 1976.

Death from silicotuberculosis has been a problem over the period of the study in underground gold miners (41 deaths) and underground mixed ore miners (35 deaths). There were two deaths from silicotuberculosis in part-time underground gold miners and one in a part-time underground mixed ore miner. There were no deaths from silicotuberculosis in other groups of miners. Out of a total of 79 deaths from this cause, 71

deaths occurred prior to 1969. The eight deaths in the period 1969 to 1977 occurred in men aged 65 years and older. This is considered to be a reflection of the changing epidemiological situation for tuberculosis.

Only in certain types of miners was an increase in non-neoplastic lung disease detectable. No such increase was detectable in nickel-copper miners, in iron ore miners or in other ore miners. A significant increase was, however, noted in underground gold miners, mixed ore miners and in uranium minrs. The cause of most of the "excess deaths" from non-neoplastic lung disease was assigned to silicosis and chronic interstitial pneumonia. In gold miners and in mixed ore miners there was less than 10 deaths from this cause expected but 179 were actually observed. This constitutes 169 "additional" deaths in these miners. In uranium miners, about 2 deaths from this cause were expected and 11 deaths actually found, producing an excess of 9 deaths from this cause. The SMR for underground gold miners and mixed ore miners for silicosis and chronic interstitial pneumonia is quite large. Considering the high concentration of silica in gold miners and also the high incidence of silicosis in these miners, these results are not surprising. The Ham Commission Report showed no increase in deaths from diseases of the respiratory system including silicosis in Ontario uranium miners. This study also does not show any significant increase in diseases of the respiratory system in uranium miners. A significant increase in deaths from silicosis and chronic interstitial pneumonia was however observed. (See Table 28).

As nickel-copper miners, iron ore miners and other ore miners show no increased risk of non-neoplastic lung disease, it can be considered most likely that a total difference between observed and expected deaths from silicosis and chronic interstitial pneumonia as well as silicotuberculosis observed in gold miners and in mixed ore miners can be actually attributed to gold mining only.

No increased rate for any type of cancer was observed in nickel-copper miners, iron ore miners or in other ore miners. One of the 3 nickel-copper miners who died of nasal cancer was employed in a sinter plant and one in a nickel refinery. Also no significant increase in deaths from cancer of the prostate in nickel-copper miners, as has been reported previously (Ro82, Sh82), could be demonstrated in this study.

There were 16 deaths from cancer of the prostate observed as compared to 14 cases expected. This difference is statistically nonsignificant.

The only increased cancer risk in non-uranium miners was observed in full-time underground gold miners and in full-time underground mixed ore miners. A total of 297 lung cancer deaths was observed in this group while only 204.4 deaths were expected, giving a SMR of 14[illegible] The increase by 93 deaths from this cause is highly statistically significant. It is for the reason stated earlier most likely that the entire increase in both underground gold miners and underground mixed ore miners is due to gold mining.

It should be noted that no increased lung cancer risk could be demonstrated in part-time underground gold miners or part-time underground mixed ore miners, strengthening the hypothesis that there is a true association between underground gold mining and increased lung cancer risk.

A significantly increased stomach cancer rate was observed in this study in underground gold miners. A similar increased risk of stomach cancer was observed also in other mining populations (En64, En72, Co74). It is however equally interesting to note that this excess in stomach cancer deaths is more than compensated in Ontario gold miners by a deficit in cancers of the intestine and rectum.

Increased lung cancer rates in various types of hard rock miners other than uranium miners have repeatedly been reported by various authors. A link has been suggested between work in British haematite mines and lung cancer (Fa56). Similarly, increased lung cancer rates as well as increased stomach cancer rates were found in Cornish tin miners (Fo81). Increased radon daughter levels were suspected in both these instances as causative agents and elevated radon daughter levels, exceeding one WL in some locations, were found in both haematite and tin mines in the United Kingdom (Du70). Similarly, increased lung cancer risk in Swedish zinc, silver and lead miners has been found (Ax71). Elevated levels of radon daughters were suspected as causative agents. In contrast, workers exposed to high concentrations of iron oxide, particularly haematite containing impurities of pentavelent arsenic and other metals, did not present any excess of lung cancer or cancer of any other site (Ax79). The much increased lung cancer risk in fluorspar

miners in Newfoundland due to exposure to high levels of radon and its short-lived daughter products is, of course, well known (de64, de66, de71).

In a study of U.S. underground metal miners, an excess mortality, largely attributable to diseases of the lung and heart, was found (Wa63). Apart from tuberculosis, malignant neoplasms of the respiratory system showed the most marked increase.

Increased lung cancer risk in gold miners exposed to an asbestiform mineral has been reported (Gi76). The mineral associated with the ore dust contained non-commercial forms of amosite asbestos. Also the number of deaths due to non-malignant respiratory diseases was greater than expected, using as controls the male population of the state in which the mine is located.

Mortality studies carried out on coal miners in England and Wales tend to suggest that there is no positive link between coal mining and cancer of the lung or between pneumoconiosis and cancer of the lung (Ke53, Go65, and Ro79). On the contrary, lung cancer rates in coal miners appeared to be less than the national rates. Some Ontario miners had worked in coal mines in the United Kingdom before coming to Canada.

In a mortality study of U.S. coal miners, more deaths than expected were found from every cause evaluated, except diabetes (En64, En72). The greatest excess was for work accidents (SMR 603), disease of the respiratory system (SMR 403) and cancer of the stomach (SMR 275). Increased death rates were found also for malignant neoplasms (SMR 162) partly due to the greater than expected number of stomach cancer deaths. Also other types of cancer including lung cancer (SMR 164) were found more frequently than expected.

However, in another study of U.S. coal miners, lower lung cancer rates than those expected from general population statistics were found (Co74).

The differences in risk for lung cancer rates observed in U.S. coal miners by individual authors might be the result of differences in the source of information used. There, however, does not appear to be a striking increase in lung cancer risk in coal miners.

A study of cancer mortality by occupation for the period 1973 to

1979 has been conducted using death abstract cards supplied by the Registrar-General of Ontario for deaths with a mention of cancer (Sp82). In 39% of the cases, information on usual occupation was either not given, or insufficient to properly classify the usual occupation. A Proportional Mortality Ratio analysis was carried out using all cancers as the reference cause of death. For the occupation "mining and quarrying", there was a significant increase in lung cancer deaths (PMR = 134, $p < 0.001$). Another finding was a deficit in malignant melanoma (PMR = 20).

It should be noted that no increased death rates for any type of cancer except cancer of the trachea, bronchus and lung was observed in the uranium miners' population as a whole, or in either of the two major mining camps. Specifically there was no increase in malignancies of the lymphatic or haematopoietic tissue or in any type of leukemia. Similarly no increased cancer risk other than lung cancer was observed in U.S. uranium miners (Wa81). The contribution to risk of cancer resulting from exposure to parts of the body other than the lung was not detectable and was, therefore, of relatively minor importance. Such contribution would result from exposure to gamma radiation and also exposure to thoron daughter products. It can, therefore, be assumed that in the conditions of uranium mining in Ontario, the contribution to risk from gamma radiation and from thoron daughters to tissues other than the lung was of minor importance. The contribution of thoron daughters to lung dose equivalent per WLM is likely to be an order of magnitude smaller than that from radon daughters. It was, therefore, decided not to make corrections for contributions to dose equivalent from external gamma radiation and inhalation of thoron daughters.

Table 28 compares the number of observed and expected deaths as well as the difference between the two values and the SMR for certain causes of death as derived by the Ham Commission and this study. There are major differences in a number of techniques used. These include the determination of Person-Years at Risk by age group from a sample of the population rather than from the total population in this study. There are also differences in the technique of the death search. The Ham Study followed the men up to the end of 1974 while this study extended the period of follow-up to the end of 1977. It is interesting to note that both the observed and expected number of lung cancer deaths greatly

increased over the 3 year period from 1974 to 1977. The increase is 47% for observed deaths and 46% for expected deaths, leaving a relatively constant SMR of 180 in 1974 and 181 in 1977. The relatively large increase in observed and expected cases over the 3 year period can be explained through aging of the population at a constant relative risk.

It is also worth noting that, putting all deaths from non-neoplastic disease of the respiratory system into one group, both the Ham Commission Report and this study showed no significant difference between observed and expected numbers of deaths from this cause group. Investigating, however, silicosis and chronic interstitial pneumonia separately from the other non-neoplastic diseases of the respiratory system, makes the differences apparent. Some of the silicosis deaths might, however, be attributable to previous gold mining.

The risk estimates for radiation induced lung cancer in Table 26 should be looked upon as a first and very crude approximation. They neglect confounding factors such as latency, possible differences in smoking habits, and effects of environmental factors other than radioactivity in the uranium mining or former non-uranium mining environment. The estimates also assume that a linear, non-threshold dose response function is applicable to the full range of exposures including the lowest exposures and that all "excess" lung cancer deaths observed in this population are solely the result of exposure to the short-lived daughters of radon-222.

Further assumptions would have to be made when extrapolating these risk factors to lifetime risk. These include assumptions as to the constancy of the risk factor observed at present over future years, survival of the study population over the future years, and future "expected" lung cancer rates. The absolute risk factor, determined in a young population such as the Ontario uranium mining population, and with no correction for latency, tends to underestimate the future absolute risk in the population. the other hand, not taking into account other confounding factors that have been mentioned previously will tend to lead to an overestimate of the absolute risk factor. The same applies to a lesser degree to the relative risk factor. Neglect of latency will tend to diminish the relative risk factor which, however, is less sensitive to the specific age distribution of the population.

Other confounding factors mentioned previously will affect the relative risk factor.

It is, nevertheless, interesting to compare these very crude preliminary results with those of two major studies of uranium miners (see Table 29). The first crude estimate of the relative risk factor derived from the Ontario Uranium miners is somewhat higher than the one derived from the Colorado plateau uranium miners, but comes very close to that derived from the Czech uranium miners. In fact, the relative risk factor of 1.5×10^{-2} per WLM derived from the average of the two estimates of the mean exposure of 53.5 Working Level Months in Ontario comes very close to that derived from the Czech uranium miners of 1.4×10^{-2} per WLM. The absolute risk factor for the Ontario uranium miners is only about one-third of that derived for the Czech uranium miners; this difference is likely largely due to differences in the ages of the two groups of miners.

It should, however, be stressed that this is only a first approximation to relative and absolute risk factors derived for the Ontario Uranium Miners population and these estimates are to be refined later.

No significant increase in work related risk could be detected in uranium mill workers. The numbers were small, however, and smaller risks could, therefore, have gone undetected.

As indicated earlier, this report covers the first part of the Study of Mortality of Ontario Miners, 1955-1977. Work is in progress at present in a number of areas that will be reported on later.

The first part of the study presented here indicates an association between gold mining and increased lung cancer risk. It is not unlikely that this increased risk is related to certain geological conditions in gold mines. These conditions do not necessarily apply in all gold mines. Data presented here indicate an increased lung cancer risk in Timmins and Fort William gold miners. This risk is somewhat less pronounced in Kirkland Lake gold miners and still less in other gold mining camps. The differences in lung cancer risk among the various gold mining camps are, however, not statistically significant. Available information indicates that individual mines in the Timmins area differ quite significantly as to their geological characteristics.

The same applies to some of the other mining camps. It is therefore planned in the second part of the study to divide underground gold miners into various sub-groups according to the geological characteristic of the mine in which they spend most of their underground mining years. Through comparison of these sub-groups we hope to identify the geological structures that might be responsible for the increased rates. At the same time materials such as air samples or dust samples are being collected in various gold mines that might assist in this work. Asbestiform materials and radioactivity are among the prime suspects. Identifying mines and causative agents that might be responsible for the increased lung cancer risk in gold miners is essential for planning and carrying out appropriate preventive measures.

The present report gives only a very crude first estimate of the relationship between exposure to radon daughters and lung cancer risk in uranium miners. This analysis is to be further refined and various confounding factors will be taken into account in the future analysis. Dose-response functions will be corrected for possible differences in smoking habits of the various groups and factors of latency will be built into the model of a dose-time-response function for radon daughters. In addition, an attempt will be made to correct the dose-response function for exposure in certain gold mines prior to start of uranium mining.

Work is in progress at present on the re-evaluation of the analysis of lung cancer deaths by cell type both in non-uranium miners and in uranium miners. The aim of this re-analysis is to establish dose-time-response functions for radon daughters using individual cell types as end-point rather than lung cancer independent of cell type, as is being done at present. This might not only improve our understanding of a dose-time-response function for radon daughters but might also indicate differences by cell type of lung cancer rates between gold miners and uranium miners.

One of the shortcomings of this study is that the elapsed time from start of exposure in uranium mines to the end of 1977 is too short to derive a reliable time-response-function for exposure to the daughter products of radon 222. The median year of entry of uranium miners into our study was 1959 (see Table 4), giving us only 18 years of observation

up to the end of 1977. Also the median age during the study period was only 39 years and lung cancer is an illness occurring rarely in men under the age of 40 years. For both these reasons it appears most desirable to carry out regular updates of the study. The study has been designed to make future updates easier and cost effective.

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APPENDIX A

TABLES

TABLE 1

ANNUAL RADON DAUGHTER CONCENTRATIONS IN MINES

WORKING LEVEL (WL)

MINE NAME & CODE(S)		1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
Bancroft Area																									
Canadian Dyno 8-3	W.R.F.			1.10	1.10	1.10	1.10	1.10																	
	Std.W.L.Mine			8.00	8.00	3.70	1.00	1.00																	
	Std.W.L.Cont.			8.00	8.00	4.90	1.10	1.10																	
	Spec.W.L.Mine			13.00	13.00	12.86	3.21	3.21																	
Bicroft 8-2	W.R.F.	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10													
	Std.W.L.Mine	2.47	2.47	3.40	1.40	1.00	1.00	0.80	0.50	0.70	0.40	0.40													
	Std.W.L.Cont.	2.47	2.47	3.40	1.40	0.90	0.80	0.70	0.40	0.60	0.60	0.60													
	Spec.W.L.Mine	4.90	4.90	3.40	3.40	4.10	3.06	2.53	1.58	2.32	1.11	1.11													
Faraday (Madawaska) 8-1	W.R.F.	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10										1.00	1.00	1.00
	Std.W.L.Mine	2.79	2.79	7.00	4.00	4.40	3.60	2.00	1.40	1.20	0.50	0.40	0.40										0.97	0.97	0.15
	Std.W.L.Cont.	2.79	2.79	7.00	4.00	4.40	3.60	1.40	1.40	2.40	0.30	0.30	0.30										0.85	0.85	0.14
	Spec.W.L.Mine	4.19	4.19	16.00	16.00	16.38	12.77	5.79	5.20	3.29	1.90	1.27	1.27										0.97	0.97	0.15
Greyhawk 8-4	W.R.F.				1.20	1.20	1.20	1.20																	
	Std.W.L.Mine				3.14	3.14	2.41	2.41																	
	Std.W.L.Cont.				2.20	2.20	2.80	2.80																	
	Spec.W.L.Mine				5.65	5.65	3.90	3.98																	
Bancroft Area 8-5,8-6,8-7,8-8,8-9	W.R.F.	1.10	1.10	1.10	1.10	1.13	1.13	1.10	1.10	1.10	1.10	1.10	1.10										1.00	1.00	1.00
	Std.W.L.Mine	2.63	2.63	5.20	5.20	3.87	2.00	1.40	0.95	1.00	0.45	0.40	0.40										0.97	0.97	0.15
	Std.W.L.Cont.	2.63	2.63	5.20	5.20	3.98	2.00	1.15	0.90	1.50	0.35	0.30	0.30										0.85	0.85	0.14
	Spec.W.L.Mine	4.54	4.54	9.70	10.60	9.75	5.76	4.16	3.39	2.81	1.46	1.27	1.27										0.97	0.97	0.15
Elliot Lake Area																									
Pronto 8A8	W.R.F.		1.00	1.00	1.20	1.07	0.95	0.86	0.96																
	Std.W.L.Mine		1.70	1.70	1.70	1.70	1.40	1.90	1.90																
	Std.W.L.Cont.		1.70	1.70	1.70	1.70	1.20	0.50	0.50																
	Spec.W.L.Mine		1.70	1.70	2.00	3.33	3.43	4.49	4.49																
Rio Algom - Quirke #1 9A1	W.R.F.		1.00	1.00	1.06	1.07	0.98	0.97	0.97					0.97	0.97	0.96	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Std.W.L.Mine		1.30	1.30	1.30	1.30	0.80	0.70	0.70					0.20	0.20	0.40	0.20	0.20	0.50	0.40	0.20	0.20	0.20	0.20	0.20
	Std.W.L.Cont.		1.30	1.30	1.30	1.70	0.70	0.50	0.50					0.30	0.30	0.40	0.33	0.17	0.25	0.40	0.15	0.14	0.11	0.10	0.17
	Spec.W.L.Mine		2.37	2.37	3.60	4.60	1.78	1.47	1.47					0.30	0.30	0.40	0.30	0.30	0.50	0.40	0.20	0.20	0.20	0.20	0.20
Rio Algom - New Quirke 9A0	W.R.F.		1.00	1.00	1.08	1.07	0.98	0.97	0.97					0.97	0.97	0.88	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Std.W.L.Mine		1.30	1.30	1.30	1.30	0.80	0.70	0.70					0.20	0.20	0.20	0.25	0.25	0.30	0.40	0.20	0.20	0.20	0.20	0.20
	Std.W.L.Cont.		1.30	1.30	1.30	1.70	0.70	0.50	0.50					0.30	0.30	0.30	0.13	0.17	0.25	0.26	0.15	0.14	0.11	0.10	0.17
	Spec.W.L.Mine		2.37	2.37	3.60	4.60	1.78	1.47	1.47					0.30	0.30	0.30	0.25	0.25	0.30	0.40	0.20	0.20	0.20	0.20	0.20
Rio Algom - Unspecified 9A2	W.R.F.		1.00	1.00	1.09	1.07	0.96	0.96	0.95	0.91	0.93	0.90	0.89	1.00	0.95	0.89	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Std.W.L.Mine		1.30	1.30	1.30	1.30	1.05	0.75	0.60	0.50	0.30	0.40	0.50	0.40	0.25	0.40	0.30	0.27	0.30	0.40	0.20	0.20	0.20	0.20	0.20
	Std.W.L.Cont.		1.30	1.30	1.30	1.60	0.95	0.70	0.50	0.50	0.30	0.30	0.50	0.40	0.40	0.30	0.22	0.15	0.25	0.26	0.15	0.14	0.11	0.10	0.17
	Spec.W.L.Mine		2.07	2.07	3.15	4.09	2.92	2.02	2.06	2.18	1.11	1.09	1.35	1.30	0.94	0.40	0.30	0.27	0.30	0.40	0.20	0.20	0.20	0.20	0.20
Rio Algom - Nordic 9A4	W.R.F.		1.00	1.00	1.09	1.06	0.94	0.94	0.95	0.91	0.93	0.90	0.89	1.00	0.92	0.92	1.00	1.00							
	Std.W.L.Mine		1.30	1.30	1.30	1.30	1.30	0.80	0.60	0.50	0.30	0.40	0.50	0.40	0.50	0.60	0.40	0.30	0.30						
	Std.W.L.Cont.		1.30	1.30	1.30	1.30	1.20	0.90	0.50	0.50	0.30	0.40	0.50	0.40	0.50	0.30	0.30	0.11	0.11						
	Spec.W.L.Mine		1.77	1.77	2.78	3.58	4.06	2.56	2.06	2.18	1.11	1.09	1.35	1.30	1.58	0.60	0.40	0.38	0.38						
Can-Met 9A8	W.R.F.			1.24	1.24	0.42	1.09	1.02	1.02																
	Std.W.L.Mine			1.50	1.50	0.50	0.60	0.60	0.60																
	Std.W.L.Cont.			1.50	1.50	0.50	0.70	0.50	0.50																
	Spec.W.L.Mine			2.00	2.00	1.00	1.10	1.00	1.00																
Denison 9A3	W.R.F.			1.27	1.27	1.12	0.99	0.94	0.97	0.95	0.98	0.98	0.93	0.92	0.98	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Std.W.L.Mine			0.70	0.70	1.30	1.50	2.10	3.30	3.10	2.70	2.90	1.70	1.20	1.20	1.10	0.70	0.70	0.60	0.60	0.60	0.60	0.60	0.30	0.70
	Std.W.L.Cont.			0.70	0.70	1.20	1.20	1.20	3.40	3.10	2.60	3.10	1.80	1.40	1.20	1.10	0.63	0.71	0.52	0.36	0.32	0.30	0.29	0.22	0.52
	Spec.W.L.Mine			2.40	2.40	3.80	4.50	4.30	5.60	6.40	5.10	5.50	4.06	3.00	2.40	1.10	0.70	0.70	0.60	0.60	0.60	0.60	0.60	0.30	0.70
Stanleigh Uranium 8A5	W.R.F.			0.88	0.88	1.14	1.02	0.99	0.99																
	Std.W.L.Mine			0.50	0.50	0.30	0.50	0.80	0.80																
	Std.W.L.Cont.			0.50	0.50	0.30	0.50	1.00	1.00																
	Spec.W.L.Mine			0.50	0.50	0.44	1.17	1.35	1.35																
Milliken Lake 8A4	W.R.F.				1.04	1.04	0.95	0.95	0.95	0.91	0.93	1.00	1.00	1.06											
	Std.W.L.Mine				0.70	0.70	0.70	0.90	0.60	0.60	0.60	0.60	3.10	3.10											
	Std.W.L.Cont.				0.70	0.70	0.60	0.90	0.70	0.60	0.70	0.70	0.50	0.50											
	Spec.W.L.Mine				1.39	1.39	1.54	1.89	1.59	1.65	1.41	1.23	10.86	10.86											
Starrock 8A7	W.R.F.			1.01	1.01	1.18	1.10	1.03	1.02	1.00	0.97	1.03	0.89	0.90	0.90	0.92	0.92								
	Std.W.L.Mine			2.50	2.50	2.50	2.68	2.70	2.90	2.00	1.90	2.00	2.10	2.30	2.00	1.50	1.50								
	Std.W.L.Cont.			2.50	2.50	2.50	0.10	0.30	0.30	2.70	1.80	1.90	0.50	0.70	1.10	2.00	2.00								
	Spec.W.L.Mine			4.80	4.80	4.80	4.90	5.00	5.20	5.10	3.80	5.60	4.40	4.60	4.30	3.60	3.60								
Northspan - Panel 9A4	W.R.F.			1.41	1.41	1.10	1.01	0.97	1.01	1.01															
	Std.W.L.Mine			1.20	1.20	0.80	1.10	0.90	1.10	1.10															
	Std.W.L.Cont.			1.20	1.20	1.00	1.20	1.00	1.10	1.10															
	Spec.W.L.Mine			1.20	1.20	1.19	2.20	1.58	1.60	1.60															
Northspan - Lake Nordic 9A5	W.R.F.			1.16	1.16	1.07	0.90	1.01	1.01																
	Std.W.L.Mine			1.00	1.00	0.80	1.00	0.90	0.90																
	Std.W.L.Cont.			1.00	1.00	0.80	1.00	0.20	0.20																
	Spec.W.L.Mine			1.00	1.00	1.78	1.88	1.71	1.71																
Northspan - Spanish Am. 9A6	W.R.F.				1.19	1.19	0.95	0.95																	
	Std.W.L.Mine				0.40	0.40	0.30	0.30																	
	Std.W.L.Cont.				0.50	0.50	0.30	0.30																	
	Spec.W.L.Mine				1.43	1.43	0.30	0.30																	
Northspan - Nashlee 9A7	W.R.F.			1.29	1.29	1.19	1.19																		
	Std.W.L.Mine			1.00	1.00	1.20	1.20																		
	Std.W.L.Cont.			1.00	1.00	1.00	1.00																		
	Spec.W.L.Mine			1.20	1.20	1.57	1.57																		
Northspan - Unspecified 9A3	W.R.F.			1.29	1.29	1.14	0.98	0.99	1.01	1.01															
	Std.W.L.Mine			1.07	1.07	0.88	0.88	0.98	1.10	1.10															
	Std.W.L.Cont.			1.07	1.07	0.82	0.83	0.68	1.10	1.10															
	Spec.W.L.Mine			1.13	1.13	1.49	1.49	1.65	1.60	1.60															
Agnew Lake 8A8	W.R.F.																				1.00	1.00	1.00	1.00	1.00
	Std.W.L.Mine																				0.14	0.14	0.41	0.77	0.16
	Std.W.L.Cont.																				0.15	0.15	0.29	0.14	0.14
	Spec.W.L.Mine																				0.14	0.14	0.41	0.77	0.16
Elliot Lake Area 8A9	W.R.F.	1.00	1.00	1.16	1.07	1.06	0.98	0.98	0.94	0.95	0.98	0.93	0.94	0.94	0.92	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Std.W.L.Mine	1.43	1.43	1.27	1.07	1.07	1.23	1.70	1.75	1.30	1.40	1.05	1.30	0.90	0.76	0.40	0.30	0.60	0.60	0.30	0.25	0.34	0.42	0.25	0.25
	Std.W.L.Cont.	1.43	1.43	1.27	1.12	0.79	0.70	1.18	1.73	1.35	1.53	0.83	0.83	0.78	0.60	0.33	0.29	0.34	0.29	0.24	0.23	0.13	0.18	0.20	0.20
	Spec.W.L.Mine	1.95	1.95	2.14	2.41	2.45	2.53	3.21	3.83	2.64	3.36	5.15	2.97	2.15	1.22	0.48	0.38	0.60	0.60	0.36	0.25	0.34	0.42	0.25	0.25

Note: For explanation of terms used in Table please refer to page 13.

Table 2

Number of Men, PYR and Mean PYR for Full-time and Part-time Underground Miners by Ore Mined

Ore	Full-time Underground			Partly Surface - Partly Underground			T o t a l		
	No. of Men	PYR	Mean PYR Per Man	No. of Men	PYR	Mean PYR Per Man	No. of Men	PYR	Mean PYR Per Man
Gold	6972	119962	17.21	570	10086	17.69	7542	130048	17.24
Ni-Cu	11337	172822	15.24	1784	21799	12.22	13121	194621	14.83
Iron	459	6450	14.05	1276	13291	10.42	1735	19741	11.38
Other	580	6800	11.72	538	2283	4.24	1118	9083	8.12
Mixed	7125	107564	15.10	1254	15022	11.98	8379	122586	14.63
Uranium							15984	241942	15.14
Asbestos							892	15097	16.92
Eldorado							1394	20684	14.84
Asbestos and Eldorado							36	589	16.36
Total file							50201	754391	15.03

Table 3

Median Values of Population Characteristics

By Ore Mined

	Uranium	Gold	Ni-Cu	Iron	Other	Mixed	Remark
1) Year of birth	1932	1913	1926	1928	1931	1925	See Fig. 4
2) Year of First Ontario mining	1957	1941	1951	1954	1957	1953	See Fig. 5
3) Years of mining	1.5	16	16	10.5	9.0	7.5	See Fig. 6
4) Year of entry into study	1959	1955*	1957	1961	1964	1959	* 57% entered in 1955 Fig. 7
5) Median age during study period	39	53	45	43	43	45	See Fig. 8

Note: Years of mining are given to the nearest half-year, other values are given to the nearest year.

Table 4

Percentage of PYR Above Age 40 by Ore Mined

Ore	Full-time Underground	Part-time Underground	Total
Uranium			46
Gold	82	81	
Ni-Cu	66	71	
Iron ore	63	68	
Others	60	55	
Mixed	67	66	
Asbestos			58
Eldorado			55

Table 5

Median Values of Population Characteristics

By Gold Mining Camp

	All Gold	Timmins	K. Lake	Ft. William	Other Camps	Mixed	Remarks
1) Year of birth	1913	1912	1914	1921	1920	1907	see fig. 10
2) Year of first Ontario mining	1941	1940	1941	1949	1945	1933	see fig. 11
3) Years of gold mining	16	19	16.5	10.5	7	18	see fig. 12
4) Year of entering study	1955 57%	1955 62%	1955 62%	1958	1958	1955 61%	see fig. 13
5) Median age during study priod	53	54	53	48	51	57	see fig. 14

Note: Years of mining are given to the nearest half-year, and other values are given to the nearest year.

Table 6

Number of Uranium Miners by Mining Camp and Prior Non-Uranium Mining Experience

Mining Camp	Previous Non-Uranium Mining: Yes	No	Total
Elliot Lake	8,525	4,256	12,781
Bancroft	1,268	1,063	2,331
Mixed	453	105	558
Others	295	19	314
TOTAL	10,541	5,443	15,984

Table 7

Median Values of Population Characteristics for Uranium Miners by Camp and Prior Non-Uranium Mining

	Bancroft			Elliot Lake			Mixed		
	Prior Non-Uranium Mining			Prior Non-Uranium Mining			Prior Non-Uranium Mining		
	Yes	No	Total	Yes	No	Total	Yes	No	Total
Year of birth	1926	1934	1930	1929	1936	1932	1928	1936	1930
First year Ontario Mining	1956	1957	1957	1956	1958	1957	1954	1957	1955
Years of Mining Uranium	1.0	1.0	1.0	1.5	1.5	1.5	2.0	2.0	2.0
Year of Entering Study	1958	1958	1958	1959	1960	1959	1958	1958	1958
Age During Study Period	43	36	39	41	35	39	41	33	39

Note: Years of mining are given to the nearest half-year, and other values to the nearest full year.

Table 8

Death Cause Groups

Causes of Death	1969-1978 ICDA Codes (Revision 8)	1955-1968 ICD Codes (Revision 6 & 7)
All Causes	000.0 - 796.9 E800.0 - E999.0	001.0 - 795.5 E800.0 - E999.0
All Disease Causes	000.0 - 796.9	001.0 - 795.5
Infective Diseases	000.0 - 136.0	001.0 - 138.1, 571.0, 630.2, 696.0, 697.0, 764.0, 767.0, 768.0, 785.6
Silicotuberculosis	010.0	001.0
Respiratory Tuberculosis	011.0 - 012.9	002.0 - 008.0
Other Tuberculosis	013.0 - 019.9	010.0 - 019.2
All Other Infective Diseases	000.0 - 009.9 020.0 - 136.0	020.0 - 138.1, 571.0, 630.2, 696.0, 697.0, 764.0, 767.0, 768.0, 785.6
Malignant Neoplasms	140.0 - 209.0	140.0 - 207.0, 292.3, 294.0
Digestive Organs	150.0 - 159.0	150.0 - 159.0
Stomach	151.0 - 151.9	151.0
Intestine, Rectum	152.0 - 154.2	152.0 - 154.0
Other Digestive	150.0 155.0 - 155.1 156.0 - 159.0	150.0, 155.0, 155.1 155.8, 156.0, 157.0 158.0, 159.0
Respiratory System	160.0 - 163.9	160.0 - 165.0
Nose, Nasal cavities, etc.	160.0 - 160.9	160.0 - 160.9
Larynx	161.0 - 161.9	161.0
Trachea, Bronchus, Lung	162.0 - 162.1	162.0, 162.1, 162.8, 163.0
Other	163.0 - 163.9	162.2, 164.0, 165.0
Lymphatic and Haematopoietic Tissue	200.0 - 209.0	200.0 - 207.9, 292.3, 294.0
Other Specific Malignancies:		
Bone	170.0 - 170.9	196.0 - 196.9
Kidney	189.0 - 189.1	180.0
Bladder	188.0, 189.2, 189.9	181.0 - 181.8

Table 7

Median Values of Population Characteristics for Uranium Miners by Camp and Prior Non-Uranium Mining

	Bancroft			Elliot Lake			Mixed		
	Prior Non-Uranium Mining			Prior Non-Uranium Mining			Prior Non-Uranium Mining		
	Yes	No	Total	Yes	No	Total	Yes	No	Total
Year of birth	1926	1934	1930	1929	1936	1932	1928	1936	1930
First year Ontario Mining	1956	1957	1957	1956	1958	1957	1954	1957	1955
Years of Mining Uranium	1.0	1.0	1.0	1.5	1.5	1.5	2.0	2.0	2.0
Year of Entering Study	1958	1958	1958	1959	1960	1959	1958	1958	1958
Age During Study Period	43	36	39	41	35	39	41	33	39

Note: Years of mining are given to the nearest half-year, and other values to the nearest full year.

Table 8

Death Cause Groups

Causes of Death	1969-1978 ICDA Codes (Revision 8)	1955-1968 ICD Codes (Revision 6 & 7)
All Causes	000.0 - 796.9 E800.0 - E999.0	001.0 - 795.5 E800.0 - E999.0
All Disease Causes	000.0 - 796.9	001.0 - 795.5
Infective Diseases	000.0 - 136.0	001.0 - 138.1, 571.0, 630.2, 696.0, 697.0, 764.0, 767.0, 768.0, 785.6
Silicotuberculosis	010.0	001.0
Respiratory Tuberculosis	011.0 - 012.9	002.0 - 008.0
Other Tuberculosis	013.0 - 019.9	010.0 - 019.2
All Other Infective Diseases	000.0 - 009.9 020.0 - 136.0	020.0 - 138.1, 571.0, 630.2, 696.0, 697.0, 764.0, 767.0, 768.0, 785.6
Malignant Neoplasms	140.0 - 209.0	140.0 - 207.0, 292.3, 294.0
Digestive Organs	150.0 - 159.0	150.0 - 159.0
Stomach	151.0 - 151.9	151.0
Intestine, Rectum	152.0 - 154.2	152.0 - 154.0
Other Digestive	150.0 155.0 - 155.1 156.0 - 159.0	150.0, 155.0, 155.1 155.8, 156.0, 157.0 158.0, 159.0
Respiratory System	160.0 - 163.9	160.0 - 165.0
Nose, Nasal cavities, etc.	160.0 - 160.9	160.0 - 160.9
Larynx	161.0 - 161.9	161.0
Trachea, Bronchus, Lung	162.0 - 162.1	162.0, 162.1, 162.8, 163.0
Other	163.0 - 163.9	162.2, 164.0, 165.0
Lymphatic and Haematopoietic Tissue	200.0 - 209.0	200.0 - 207.9, 292.3, 294.0
Other Specific Malignancies:		
Bone	170.0 - 170.9	196.0 - 196.9
Kidney	189.0 - 189.1	180.0
Bladder	188.0, 189.2, 189.9	181.0 - 181.8

Causes of Death	1969-1978 ICDA Codes (Revision 8)	1955-1968 ICD Codes (Revision 6 & 7)
Other Specific Malignancies (cont'd)		
Brain	191.0, 192.0 - 192.9	193.0 - 193.9
Prostate	185.0	177.0
Skin	172.0 - 173.9	190.0 - 191.9
All Other Malignancies	140.0 - 149.0, 171.0 - 171.3 171.9, 174.0, 180.0 - 181.0 182.0 - 184.9, 186.0, 187.0 - 187.9, 190.0, 193.0 - 198.5, 198.9, 199.0 - 199.1	140.0 - 148.0, 170.0 - 174.0 175.0 - 176.9, 178.0, 179.0 - 179.9, 192.0, 199.0, 194.0 - 195.8 197.0 - 198.9
Diseases of Circulatory System	289.1 - 289.3 390.0 - 458.9	330.0 - 334.0 400.0 - 468.3, 570.2
Ischaemic Heart Disease	410.0 - 414.9	420.0 - 420.2
Cerebrovascular Disease	430.0 - 438.9	330.0 - 334.0
Other	289.1 - 289.3 390.0 - 404.0 420.0 - 429.9 440.0 - 458.9	400.0 - 416.0 421.0 - 468.3 570.2
Diseases of Respiratory System	460.0 - 519.9	240.0, 241.0, 470.0 - 527.2, 763.0
Influenza, Pneumonia, Bronchitis, Asthma	470.0 - 474.0 480.0 - 486.0 490.0 - 493.0	480.0 - 483.0 490.0 - 493.0, 241.0 501.0 - 502.1, 527.1
Silicosis, Chronic Interstitial Pneumonia	460.0 - 466.0 515.0 - 517.0	470.0 - 475.0, 500.0 523.0 - 525.0
Other Respiratory	500.0 - 508.9 510.0 - 514.0 518.0 - 519.9	240.0 510.0 - 522.0, 527.2 526.0 - 527.0
All Other Disease Causes	571.0, 571.8, 571.9 520.0 - 570.0, 572.0 - 577.9 740.0 - 759.9 210.0 - 279.0, 280.0 - 289.0 289.4 - 389.9, 580.0 - 738.9 760.0 - 794.0, 796.0 - 796.1 795.0 - 795.2 1969-1978	581.0, 581.1, 298.0 530.0 - 570.1 570.3 - 570.5, 572.0 - 580.0, 784.6, 582.0 - 587.3, 220.0 325.4, 710.2, 711.0, 745.0 - 753.0, 754.0 759.3 210.0 - 219.0, 221.0 - 239.0, 1955-1968

Causes of Death	ICDA Codes (Revision 8)	ICD Codes (Revision 6 & 7)
All Other Disease Causes (cont'd)	796.2 - 796.9	242.0 - 245.0, 290.0 - 292.0 292.4 - 293.0, 295.0 - 297.0 298.1, 300.0 - 325.3, 325.5. - 326.4, 340.0 - 354.0, 356.0 - 398.3, 590.0 - 630.1, 631.0 - 695.0, 698.0 - 710.1, 710.3 - 710.5, 712.0 - 744.2, 760.0 - 762.5, 765.0 - 766.5, 769.0 - 771.5, 773.0 - 776.0, 780.0 - 784.5, 784.7 - 785.5, 785.7 - 789.7, 790.0, 790.2 - 795.5, 250.0 - 289.2, 299.0, 355.0, 753.1, 789.8, 790.1, 772.0
Accidents, Poisoning, Violence	E800.0 - E999.0	E800.0 - E999.0
Motor Vehicle Traffic Accidents	E810.0 - E819.9	E810.0 - E825.9
Water Transport Accidents	E830.0 - E838.9	E850.0 - E858.0
Accidental Falls	E880.0 - E887.0	E900.0 - E904.0
Motor vehicle Non-Traffic Accidents	E820.0 - E823.0	E830.0 - E835.9
Accidental Drowning and Submersion	E910.0	E929.0
Inhalation or Ingestion of Food Causing Obstruction	E911.0	E921.0
Blow from Falling or Projected Missile	E916.0, E917.0	E910.0
Firearms or Explosives	E922.0, E923.1, E923.8	E919.0
Other Vehicle Accidents	E927.0	E911.0
All Other Accidents	E850.0 - E877.0	E870.0 - E895.0
	E900.0 - E909.0	E927.0 - E928.0
	E928.0, E800.0 - E807.9	E930.0 - E935.0
	E825.0 - E827.9	E912.0, E800.0 - E802.0
	E840.0 - E845.9	E840.0 - E845.0
	E890.0 - E899.0	E860.0 - E866.0
	E912.0 - E915.0	E913.0 - E918.0
	E918.0 - E921.0, E923.0,	E920.0, E922.0 - E925.0
	E923.2, E923.9, E924.0 - E926.0	E936.0, E940.0 - E962.0
	E929.0, E930.0 - E949.0	E965.0, E984.0 - E999.0
	E950.0 - E959.0	E970.0 - E979.0, E963.0
	E960.0 - E969.0	E980.0 - E983.0, E964.0
	E970.0 - E999.0	

Table 9

Mortality Data
Underground Nickel/Copper Miners

Cause of Death	Observed	Expected	SMR	P-value
All Causes	1341	1444.58	93	
All Disease Causes	1108	1276.96	87	
Infective Diseases	9	10.17	88	
Silicotuberculosis	0	0.28	0	
Respiratory Tuberculosis	1	3.68	27	
Other Tuberculosis	1	0.97	103	
All Other Infective Diseases	7	5.25	133	
Malignant Neoplasms	261	308.28	85	
Digestive Organs	89	101.30	88	
Stomach	27	25.04	108	
Intestine, Rectum	35	42.55	82	
Other Digestive	27	33.71	80	
Respiratory System	91	102.30	89	
Nose, Nasal Cavities etc	3	0.92	327	
Larynx	4	4.62	87	
Trachea, Bronchus, Lung	83	95.95	87	
Other	1	0.82	123	
Lymphatic and Haematopoietic Tissue	24	30.54	79	
Other	57	74.14	77	
Bone	3	1.49	202	
Kidney	7	7.81	90	
Bladder	7	8.79	80	
Brain	16	12.85	125	
Prostate	16	13.96	115	
Skin	0	4.73	0	
All Other	8	24.51	33	
Diseases of Circulatory System	678	728.37	93	
Ischaemic Heart Disease	545	555.11	98	
Cerebrovascular Disease	74	85.45	87	
Other	59	87.81	67	
Diseases of Respiratory System	55	76.17	72	
Influenza, Pneumonia, Bronchitis, Asthma	47	61.90	76	
Silicosis, Chronic Interstitial Pneumonia	5	3.64	137	
Other	3	10.63	28	
All Other Disease Causes	105	153.96	68	
Accidents, Poisoning, Violence	233	167.62	139	2.2E-07
Motor Vehicle Traffic Accidents	55	49.95	110	
Water Transport Accidents	12	6.29	191	2.8E-02
Accidental Falls	15	13.82	109	
Motor Vehicle Non-Traffic Accidents	0	1.32	0	
Accidental Drowning and Submersion	8	5.83	137	
Inhalation or Ingestion of Food Causing Obstruction	5	3.09	162	
Blow from Falling or Projected Missile	30	4.24	708	0.0E+00
Firearms or Explosives	3	1.81	166	
Other Vehicle Accidents	4	1.32	304	4.5E-02
All Other Accidents	101	79.95	126	9.3E-03

Table 9a

Mortality Data

Nickel/Copper Miners Who Worked Part-time Underground & Part-time on the Surface

Cause of Death	Observed	Expected	SMR	P-value
All Causes	171	223.82	76	
All Disease Causes	154	202.01	76	
Infective Diseases	0	1.52	0	
Silicotuberculosis	0	0.05	0	
Respiratory Tuberculosis	0	0.55	0	
Other Tuberculosis	0	0.15	0	
All Other Infective Diseases	0	0.78	0	
Malignant Neoplasms	47	48.74	96	
Digestive Organs	12	16.21	74	
Stomach	2	4.02	50	
Intestine, Rectum	5	6.82	73	
Other Digestive	5	5.38	93	
Respiratory System	21	16.40	128	
Nose, Nasal Cavities etc	0	0.14	0	
Larynx	1	0.73	137	
Trachea, Bronchus, Lung	20	15.41	130	
Other	0	0.12	0	
Lymphatic and Haematopoietic Tissue	4	4.54	88	
Other	10	11.60	86	
Bone	0	0.22	0	
Kidney	2	1.22	165	
Bladder	0	1.49	0	
Brain	0	1.82	0	
Prostate	2	2.46	81	
Skin	1	0.67	149	
All Other	5	3.73	134	
Diseases of Circulatory System	88	116.37	76	
Ischaemic Heart Disease	64	88.32	72	
Cerebrovascular Disease	14	14.08	99	
Other	10	13.98	72	
Diseases of Respiratory System	5	12.46	40	
Influenza, Pneumonia, Bronchitis, Asthma	5	10.13	49	
Silicosis, Chronic Interstitial Pneumonia	0	0.60	0	
Other	0	1.72	0	
All Other Disease Causes	14	22.91	61	
Accidents, Poisoning, Violence	17	21.81	78	
Motor Vehicle Traffic Accidents	5	6.34	79	
Water Transport Accidents	3	0.75	398	4.1E-02
Accidental Falls	2	1.98	101	
Motor Vehicle Non-Traffic Accidents	0	0.17	0	
Accidental Drowning and Submersion	0	0.74	0	
Inhalation or Ingestion of Food Causing Obstruction	0	0.43	0	
Blow from Falling or Projected Missile	2	0.51	389	
Firearms or Explosives	0	0.22	0	
Other Vehicle Accidents	0	0.19	0	
All Other Accidents	5	10.49	48	

Table 10

Mortality Data
Underground Gold Miners

Cause of Death	Observed	Expected	SMR	P-value
All Causes	2007	2097.84	96	
All Disease Causes	1777	1963.41	91	
Infective Diseases	52	14.27	364	4.0E-11
Silicotuberculosis	41	0.67	6140	0.0E+00
Respiratory Tuberculosis	5	5.33	94	
Other Tuberculosis	0	1.25	0	
All Other Infective Diseases	6	7.02	85	
Malignant Neoplasms	428	447.04	96	
Digestive Organs	130	155.22	84	
Stomach	60	40.40	148	2.3E-03
Intestine, Rectum	28	65.36	43	
Other Digestive	42	49.46	85	
Respiratory System	202	143.38	141	4.9E-07
Nose, Nasal Cavities etc	1	1.12	89	
Larynx	5	6.27	80	
Trachea, Bronchus, Lung	196	134.90	145	7.2E-08
Other	0	1.09	0	
Lymphatic and Haematopoietic Tissue	28	38.58	73	
Other	68	109.85	62	
Bone	0	1.83	0	
Kidney	10	10.40	96	
Bladder	6	16.84	36	
Brain	9	12.12	74	
Prostate	20	32.73	61	
Skin	1	4.92	20	
All Other	22	31.01	71	
Diseases of Circulatory System	883	1167.27	76	
Ischaemic Heart Disease	614	850.06	72	
Cerebrovascular Disease	145	168.72	86	
Other	124	148.50	84	
Diseases of Respiratory System	251	137.11	183	0.0E+00
Influenza, Pneumonia, Bronchitis, Asthma	123	113.93	108	
Silicosis, Chronic Interstitial Pneumonia	111	6.58	1688	0.0E+00
Other	17	16.60	102	
All Other Disease Causes	163	197.73	82	
Accidents, Poisoning, Violence	230	134.43	171	0.0E+00
Motor Vehicle Traffic Accidents	35	38.32	91	
Water Transport Accidents	12	4.05	296	1.0E-03
Accidental Falls	23	17.50	131	
Motor Vehicle Non-Traffic Accidents	0	1.02	0	
Accidental Drowning and Submersion	5	4.41	113	
Inhalation or Ingestion of Food Causing Obstruction	2	2.84	70	
Blow from Falling or Projected Missile	49	2.84	1728	0.0E+00
Firearms or Explosives	12	1.29	928	1.4E-08
Other Vehicle Accidents	4	0.82	486	1.0E-02
All Other Accidents	88	61.33	143	7.9E-04

Table 10a

Mortality Data

Gold Miners Who Worked Part-time Underground & Part-time on the Surface

Cause of Death	Observed	Expected	SMR	P-value
All Causes	143	167.51	85	
All Disease Causes	133	156.32	85	
Infective Diseases	4	1.13	352	2.8E-02
Silicotuberculosis	2	0.05	3908	1.3E-03
Respiratory Tuberculosis	1	0.42	237	
Other Tuberculosis	0	0.10	0	
All Other Infective Diseases	1	0.56	178	
Malignant Neoplasms	33	35.54	93	
Digestive Organs	12	12.31	98	
Stomach	4	3.19	126	
Intestine, Rectum	5	5.19	96	
Other Digestive	3	3.93	76	
Respiratory System	12	11.40	105	
Nose, Nasal Cavities etc	0	0.09	0	
Larynx	1	0.50	199	
Trachea, Bronchus, Lung	11	10.72	103	
Other	0	0.09	0	
Lymphatic and Haematopoietic Tissue	3	3.08	97	
Other	6	8.75	69	
Bone	0	0.15	0	
Kidney	0	0.83	0	
Bladder	1	1.32	76	
Brain	2	1.00	200	
Prostate	0	2.55	0	
Skin	0	0.40	0	
All Other	3	2.50	120	
Diseases of Circulatory System	79	92.91	85	
Ischaemic Heart Disease	54	67.77	80	
Cerebrovascular Disease	12	13.31	90	
Other	13	11.83	110	
Diseases of Respiratory System	5	10.83	46	
Influenza, Pneumonia, Bronchitis, Asthma	4	9.02	44	
Silicosis, Chronic Interstitial Pneumonia	1	0.51	196	
Other	0	1.30	0	
All Other Disease Causes	12	15.90	75	
Accidents, Poisoning, Violence	10	11.19	89	
Motor Vehicle Traffic Accidents	2	3.19	63	
Motor Transport Accidents	0	0.35	0	
Accidental Falls	2	1.43	139	
Motor Vehicle Non-Traffic Accidents	0	0.09	0	
Accidental Drowning and Submersion	1	0.37	271	
Inhalation or Ingestion of Food Causing Obstruction	0	0.23	0	
Blow from Falling or Projected Missile	0	0.24	0	
Firearms or Explosives	0	0.11	0	
Other Vehicle Accidents	0	0.07	0	
All Other Accidents	5	5.11	98	

Table 11

Mortality Data
Iron Ore Miners Working in Full-time Dust Exposure

Cause of Death	Observed	Expected	SMR	P-value
All Causes	35	40.85	86	
All Disease Causes	28	34.80	80	
Infective Diseases	0	0.27	0	
Silicotuberculosis	0	0.01	0	
Respiratory Tuberculosis	0	0.09	0	
Other Tuberculosis	0	0.03	0	
All Other Infective Diseases	0	0.15	0	
Malignant Neoplasms	2	8.59	23	
Digestive Organs	2	2.73	73	
Stomach	0	0.66	0	
Intestine, Rectum	2	1.15	174	
Other Digestive	0	0.93	0	
Respiratory System	0	2.84	0	
Nose, Nasal Cavities etc	0	0.03	0	
Larynx	0	0.13	0	
Trachea, Bronchus, Lung	0	2.65	0	
Other	0	0.02	0	
Lymphatic and Haematopoietic Tissue	0	0.93	0	
Other	0	2.09	0	
Bone	0	0.05	0	
Kidney	0	0.23	0	
Bladder	0	0.21	0	
Brain	0	0.43	0	
Prostate	0	0.29	0	
Skin	0	0.16	0	
All Other	0	0.74	0	
Diseases of Circulatory System	19	19.31	98	
Ischaemic Heart Disease	14	14.94	94	
Cerebrovascular Disease	3	2.08	144	
Other	2	2.29	87	
Diseases of Respiratory System	1	1.90	53	
Influenza, Pneumonia, Bronchitis, Asthma	0	1.54	0	
Silicosis, Chronic Interstitial Pneumonia	0	0.09	0	
Other	1	0.28	361	
All Other Disease Causes	6	4.73	127	
Accidents, Poisoning, Violence	7	6.05	116	
Motor Vehicle Traffic Accidents	2	1.80	111	
Water Transport Accidents	0	0.23	0	
Accidental Falls	0	0.44	0	
Motor Vehicle Non-Traffic Accidents	0	0.05	0	
Accidental Drowning and Submersion	0	0.20	0	
Inhalation or Ingestion of Food Causing Obstruction	0	0.11	0	
Blow from Falling or Projected Missile	1	0.16	632	
Firearms or Explosives	1	0.06	1624	
Other Vehicle Accidents	1	0.05	1951	5.0E-02
All Other Accidents	2	2.94	68	

Table 11a

Mortality Data
Iron Ore Miners Who Worked Part-time in Dust Exposure

Cause of Death	Observed	Expected	SMR	P-value
All Causes	106	115.42	92	
All Disease Causes	92	102.46	90	
Infective Diseases	0	0.73	0	
Silicotuberculosis	0	0.02	0	
Respiratory Tuberculosis	0	0.24	0	
Other Tuberculosis	0	0.08	0	
All Other Infective Diseases	0	0.39	0	
Malignant Neoplasms	22	24.71	89	
Digestive Organs	6	8.08	74	
Stomach	2	1.97	102	
Intestine, Rectum	2	3.42	59	
Other Digestive	2	2.70	74	
Respiratory System	8	8.19	98	
Nose, Nasal Cavities etc	0	0.07	0	
Larynx	1	0.38	266	
Trachea, Bronchus, Lung	7	7.67	91	
Other	0	0.06	0	
Lymphatic and Haematopoietic Tissue	3	2.42	124	
Other	5	6.03	83	
Bone	0	0.12	0	
Kidney	2	0.62	320	
Bladder	2	0.71	280	
Brain	0	1.01	0	
Prostate	0	1.20	0	
Skin	0	0.39	0	
All Other	1	1.98	51	
Diseases of Circulatory System	57	58.36	98	
Ischaemic Heart Disease	45	44.21	102	
Cerebrovascular Disease	8	7.08	113	
Other	4	7.07	57	
Diseases of Respiratory System	7	6.21	113	
Influenza, Pneumonia, Bronchitis, Asthma	6	5.04	119	
Silicosis, Chronic Interstitial Pneumonia	0	0.29	0	
Other	1	0.89	113	
All Other Disease Causes	6	12.44	48	
Accidents, Poisoning, Violence	14	12.96	108	
Motor Vehicle Traffic Accidents	4	3.73	107	
Water Transport Accidents	1	0.45	220	
Accidental Falls	0	1.12	0	
Motor Vehicle Non-Traffic Accidents	0	0.10	0	
Accidental Drowning and Submersion	0	0.43	0	
Inhalation or Ingestion of Food Causing Obstruction	0	0.26	0	
Blow from Falling or Projected Missile	1	0.31	318	
Firearms or Explosives	1	0.12	818	
Other Vehicle Accidents	1	0.12	837	
All Other Accidents	6	6.32	95	

Table 12

Mortality Data
'Other Ore' Underground Miners

Cause of Death	Observed	Expected	SMR	P-value
All Causes	57	75.09	76	
All Disease Causes	52	68.18	76	
Infective Diseases	1	0.47	213	
Silicotuberculosis	0	0.02	0	
Respiratory Tuberculosis	0	0.16	0	
Other Tuberculosis	0	0.04	0	
All Other Infective Diseases	1	0.25	399	
Malignant Neoplasms	15	14.38	104	
Digestive Organs	3	4.98	60	
Stomach	1	1.29	77	
Intestine, Rectum	0	2.13	0	
Other Digestive	2	1.56	128	
Respiratory System	5	4.10	122	
Nose, Nasal Cavities etc	0	0.04	0	
Larynx	0	0.19	0	
Trachea, Bronchus, Lung	5	3.83	131	
Other	0	0.04	0	
Lymphatic and Haematopoietic Tissue	2	1.38	145	
Other	5	3.92	127	
Bone	0	0.07	0	
Kidney	0	0.32	0	
Bladder	0	0.55	0	
Brain	1	0.45	221	
Prostate	1	1.21	83	
Skin	0	0.22	0	
All Other	3	1.10	274	
Diseases of Circulatory System	24	40.83	59	
Ischaemic Heart Disease	16	28.55	56	
Cerebrovascular Disease	4	6.56	61	
Other	4	5.72	70	
Diseases of Respiratory System	5	4.94	101	
Influenza, Pneumonia, Bronchitis, Asthma	5	4.20	119	
Silicosis, Chronic Interstitial Pneumonia	0	0.20	0	
Other	0	0.54	0	
All Other Disease Causes	7	7.56	93	
Accidents, Poisoning, Violence	5	6.91	72	
Motor Vehicle Traffic Accidents	1	2.03	49	
Water Transport Accidents	0	0.23	0	
Accidental Falls	0	0.81	0	
Motor Vehicle Non-Traffic Accidents	0	0.05	0	
Accidental Drowning and Submersion	1	0.22	447	
Inhalation or Ingestion of Food Causing Obstruction	0	0.13	0	
Blow from Falling or Projected Missile	1	0.16	636	
Firearms or Explosives	0	0.06	0	
Other Vehicle Accidents	1	0.06	1669	
All Other Accidents	1	3.17	32	

Table 12a

Mortality Data

'Other Ore' Miners Who Worked Part-time Underground & Part-time Surface

Cause of Death	Observed	Expected	SMR	P-value
All Causes	18	17.85	101	
All Disease Causes	16	15.70	102	
Infective Diseases	0	0.10	0	
Silicotuberculosis	0	0.00	0	
Respiratory Tuberculosis	0	0.03	0	
Other Tuberculosis	0	0.01	0	
All Other Infective Diseases	0	0.06	0	
Malignant Neoplasms	1	3.87	26	
Digestive Organs	0	1.24	0	
Stomach	0	0.29	0	
Intestine, Rectum	0	0.53	0	
Other Digestive	0	0.42	0	
Respiratory System	1	1.29	78	
Nose, Nasal Cavities etc	0	0.01	0	
Larynx	0	0.06	0	
Trachea, Bronchus, Lung	1	1.21	83	
Other	0	0.01	0	
Lymphatic and Haematopoietic Tissue	0	0.37	0	
Other	0	0.96	0	
Bone	0	0.02	0	
Kidney	0	0.09	0	
Bladder	0	0.11	0	
Brain	0	0.15	0	
Prostate	0	0.20	0	
Skin	0	0.07	0	
All Other	0	0.32	0	
Diseases of Circulatory System	14	8.81	159	
Ischaemic Heart Disease	11	6.57	167	
Cerebrovascular Disease	1	1.13	89	
Other	2	1.12	179	
Diseases of Respiratory System	0	0.97	0	
Influenza, Pneumonia, Bronchitis, Asthma	0	0.77	0	
Silicosis, Chronic Interstitial Pneumonia	0	0.04	0	
Other	0	0.16	0	
All Other Disease Causes	1	1.95	51	
Accidents, Poisoning, Violence	2	2.15	93	
Motor Vehicle Traffic Accidents	0	0.61	0	
Water Transport Accidents	1	0.07	1494	
Accidental Falls	0	0.17	0	
Motor Vehicle Non-Traffic Accidents	0	0.01	0	
Accidental Drowning and Submersion	0	0.07	0	
Inhalation or Ingestion of Food Causing Obstruction	0	0.04	0	
Blow from Falling or Projected Missile	0	0.05	0	
Firearms or Explosives	0	0.02	0	
Other Vehicle Accidents	0	0.03	0	
All Other Accidents	1	1.09	92	

Table 13

Mortality Data
Mixed Ore Underground Miners

Cause of Death	Observed	Expected	SMR	P-value
All Causes	1163	1157.14	101	
All Disease Causes	978	1048.60	93	
Infective Diseases	49	7.84	625	0.0E+00
Silicotuberculosis	35	0.30	11517	0.0E+00
Respiratory Tuberculosis	7	2.82	248	2.5E-02
Other Tuberculosis	3	0.70	431	3.4E-02
All Other Infective Diseases	4	4.02	100	
Malignant Neoplasms	219	237.73	92	
Digestive Organs	63	80.98	78	
Stomach	22	20.78	106	
Intestine, Rectum	23	34.17	67	
Other Digestive	18	26.02	69	
Respiratory System	103	74.12	139	4.0E-04
Nose, Nasal Cavities etc	0	0.65	0	
Larynx	2	3.37	59	
Trachea, Bronchus, Lung	101	69.48	145	7.8E-05
Other	0	0.61	0	
Lymphatic and Haematopoietic Tissue	14	22.50	62	
Other	39	60.14	65	
Bone	0	1.10	0	
Kidney	6	5.66	106	
Bladder	5	8.21	61	
Brain	5	8.13	62	
Prostate	10	15.75	63	
Skin	0	3.36	0	
All Other	13	17.92	73	
Diseases of Circulatory System	476	615.95	77	
Ischaemic Heart Disease	358	448.98	80	
Cerebrovascular Disease	61	87.10	70	
Other	57	79.87	71	
Diseases of Respiratory System	133	69.87	190	0.0E+00
Influenza, Pneumonia, Bronchitis, Asthma	62	58.14	107	
Silicosis, Chronic Interstitial Pneumonia	68	3.19	2134	0.0E+00
Other	3	8.55	35	
All Other Disease Causes	101	117.21	86	
Accidents, Poisoning, Violence	185	108.54	170	0.0E+00
Motor Vehicle Traffic Accidents	49	32.06	153	3.2E-03
Water Transport Accidents	3	3.80	79	
Accidental Falls	19	11.11	171	1.9E-02
Motor Vehicle Non-Traffic Accidents	1	0.83	121	
Accidental Drowning and Submersion	7	3.67	191	
Inhalation or Ingestion of Food Causing Obstruction	3	2.03	147	
Blow from Falling or Projected Missile	24	2.59	926	2.0E-11
Firearms or Explosives	9	1.09	826	2.2E-06
Other Vehicle Accidents	0	0.82	0	
All Other Accidents	70	50.52	139	5.4E-03

Table 13a

Mortality Data

Mixed Ore Miners Who Worked Part-time Underground & Part-time on the Surface

Cause of Death	Observed	Expected	SMR	P-value
All Causes	104	144.89	72	
All Disease Causes	91	130.03	70	
Infective Diseases	1	0.94	107	
Silicotuberculosis	1	0.03	3285	3.0E-02
Respiratory Tuberculosis	0	0.32	0	
Other Tuberculosis	0	0.09	0	
All Other Infective Diseases	0	0.49	0	
Malignant Neoplasms	26	30.77	85	
Digestive Organs	6	10.21	59	
Stomach	2	2.52	79	
Intestine, Rectum	2	4.32	46	
Other Digestive	2	3.37	59	
Respiratory System	9	10.05	90	
Nose, Nasal Cavities etc	0	0.09	0	
Larynx	0	0.46	0	
Trachea, Bronchus, Lung	9	9.43	95	
Other	0	0.08	0	
Lymphatic and Haematopoietic Tissue	3	2.93	102	
Other	8	7.58	106	
Bone	0	0.14	0	
Kidney	1	0.76	132	
Bladder	2	0.96	209	
Brain	2	1.16	173	
Prostate	1	1.70	59	
Skin	1	0.45	220	
All Other	1	2.41	42	
Diseases of Circulatory System	49	74.94	65	
Ischaemic Heart Disease	37	56.01	66	
Cerebrovascular Disease	6	9.65	62	
Other	6	9.28	65	
Diseases of Respiratory System	8	8.24	97	
Influenza, Pneumonia, Bronchitis, Asthma	6	6.75	89	
Silicosis, Chronic Interstitial Pneumonia	2	0.38	528	
Other	0	1.12	0	
All Other Disease Causes	7	15.14	46	
Accidents, Poisoning, Violence	13	14.87	87	
Motor Vehicle Traffic Accidents	0	4.31	0	
Water Transport Accidents	0	0.51	0	
Accidental Falls	4	1.38	290	
Motor Vehicle Non-Traffic Accidents	0	0.11	0	
Accidental Drowning and Submersion	0	0.50	0	
Inhalation or Ingestion of Food Causing Obstruction	0	0.29	0	
Blow from Falling or Projected Missile	0	0.35	0	
Firearms or Explosives	2	0.14	1412	9.1E-03
Other Vehicle Accidents	0	0.14	0	
All Other Accidents	7	7.13	98	

Table 14

Mortality Data
Uranium Miners

Cause of Death	Observed	Expected	SMR	P-value
All Causes	1316	1113.77	118	6.8E-10
All Disease Causes	819	890.94	92	
Infective Diseases	6	7.39	81	
Silicotuberculosis	0	0.09	0	
Respiratory Tuberculosis	2	2.18	92	
Other Tuberculosis	2	0.76	265	
All Other Infective Diseases	2	4.36	46	
Malignant Neoplasms	259	222.24	117	6.8E-03
Digestive Organs	64	68.08	94	
Stomach	21	16.10	130	
Intestine, Rectum	23	28.67	80	
Other Digestive	20	23.31	86	
Respiratory System	121	70.54	172	9.4E-10
Nose, Nasal Cavities etc	0	0.76	0	
Larynx	2	3.33	60	
Trachea, Bronchus, Lung	119	65.78	181	3.0E-11
Other	0	0.67	0	
Lymphatic and Haematopoietic Tissue	26	27.35	95	
Other	48	56.27	85	
Bone	2	1.38	145	
Kidney	6	5.79	104	
Bladder	0	4.75	0	
Brain	13	12.73	102	
Prostate	5	6.17	81	
Skin	4	4.89	82	
All Other	18	20.56	88	
Diseases of Circulatory System	396	480.41	82	
Ischaemic Heart Disease	292	371.81	79	
Cerebrovascular Disease	46	50.32	91	
Other	58	58.27	100	
Diseases of Respiratory System	53	47.83	111	
Influenza, Pneumonia, Bronchitis, Asthma	35	38.32	91	
Silicosis, Chronic Interstitial Pneumonia	11	2.14	514	1.5E-05
Other	7	7.37	95	
All Other Disease Causes	105	133.07	79	
Accidents, Poisoning, Violence	497	222.82	223	0.0E+00
Motor Vehicle Traffic Accidents	148	73.93	200	0.0E+00
Water Transport Accidents	20	9.24	217	1.4E-03
Accidental Falls	42	13.38	314	3.8E-10
Motor Vehicle Non-Traffic Accidents	5	1.83	273	3.9E-02
Accidental Drowning and Submersion	13	7.98	163	
Inhalation or Ingestion of Food Causing Obstruction	5	3.38	148	
Blow from Falling or Projected Missile	63	5.92	1065	0.0E+00
Firearms or Explosives	15	2.44	614	5.2E-08
Other Vehicle Accidents	21	1.89	1112	0.0E+00
All Other Accidents	165	102.82	160	4.4E-10

Table 15

Mortality Data

Ever Mill, Never Uranium Underground Worker Excluding Asbestos & Eldorado

Cause of Death	Observed	Expected	SMR	P-value
All Causes	8	7.93	101	
All Disease Causes	7	6.55	107	
Infective Diseases	0	0.05	0	
Silicotuberculosis	0	0.00	0	
Respiratory Tuberculosis	0	0.01	0	
Other Tuberculosis	0	0.01	0	
All Other Infective Diseases	0	0.03	0	
Malignant Neoplasms	3	1.65	181	
Digestive Organs	1	0.51	194	
Stomach	0	0.12	0	
Intestine, Rectum	1	0.22	459	
Other Digestive	0	0.18	0	
Respiratory System	1	0.55	183	
Nose, Nasal Cavities etc	0	0.01	0	
Larynx	0	0.02	0	
Trachea, Bronchus, Lung	1	0.51	195	
Other	0	0.00	0	
Lymphatic and Haemtopoietic Tissue	0	0.18	0	
Other	1	0.41	245	
Bone	0	0.01	0	
Kidney	0	0.04	0	
Bladder	0	0.04	0	
Brain	1	0.08	1249	
Prostate	0	0.06	0	
Skin	0	0.03	0	
All Other	0	0.15	0	
Diseases of Circulatory System	3	3.58	84	
Ischaemic Heart Disease	3	2.76	109	
Cerebrovascular Disease	0	0.40	0	
Other	0	0.43	0	
Diseases of Respiratory System	0	0.38	0	
Influenza, Pneumonia, Bronchitis, Asthma	0	0.30	0	
Silicosis, Chronic Interstitial Pneumonia	0	0.02	0	
Other	0	0.06	0	
All Other Disease Causes	1	0.89	112	
Accidents, Poisoning, Violence	1	1.38	73	
Motor Vehicle Traffic Accidents	0	0.47	0	
Water Transport Accidents	0	0.05	0	
Accidental Falls	0	0.08	0	
Motor Vehicle Non-Traffic Accidents	0	0.01	0	
Accidental Drowning and Submersion	0	0.05	0	
Inhalation or Ingestion of Food Causing Obstruction	1	0.02	4626	2.1E-02
Blow from Falling or Projected Missile	0	0.03	0	
Firearms or Explosives	0	0.01	0	
Other Vehicle Accidents	0	0.01	0	
All Other Accidents	0	0.62	0	

Table 16

Mortality Data
Ever Uranium Mill Worker Excluding Asbestos & Eldorado

Cause of Death	Observed	Expected	SMR	P-value
All Causes	41	36.41	113	
All Disease Causes	28	28.94	97	
Infective Diseases	0	0.23	0	
Silicotuberculosis	0	0.00	0	
Respiratory Tuberculosis	0	0.07	0	
Other Tuberculosis	0	0.02	0	
All Other Infective Diseases	0	0.14	0	
Malignant Neoplasms	9	7.21	125	
Digestive Organs	2	2.21	91	
Stomach	0	0.52	0	
Intestine, Rectum	2	0.93	214	
Other Digestive	0	0.75	0	
Respiratory System	4	2.28	176	
Nose, Nasal Cavities etc	0	0.02	0	
Larynx	0	0.11	0	
Trachea, Bronchus, Lung	4	2.13	188	
Other	0	0.02	0	
Lymphatic and Haematopoietic Tissue	0	0.89	0	
Other	3	1.85	163	
Bone	0	0.05	0	
Kidney	1	0.18	545	
Bladder	0	0.16	0	
Brain	1	0.40	250	
Prostate	0	0.23	0	
Skin	0	0.16	0	
All Other	1	0.67	150	
Diseases of Circulatory System	15	15.62	96	
Ischaemic Heart Disease	15	12.00	125	
Cerebrovascular Disease	0	1.71	0	
Other	0	1.91	0	
Diseases of Respiratory System	1	1.61	62	
Influenza, Pneumonia, Bronchitis, Asthma	0	1.29	0	
Silicosis, Chronic Interstitial Pneumonia	1	0.07	1408	
Other	0	0.25	0	
All Other Disease Causes	3	4.26	70	
Accidents, Poisoning, Violence	13	7.47	174	4.2E-02
Motor Vehicle Traffic Accidents	6	2.57	233	4.7E-02
Water Transport Accidents	0	0.31	0	
Accidental Falls	0	0.43	0	
Motor Vehicle Non-Traffic Accidents	0	0.06	0	
Accidental Drowning and Submersion	0	0.27	0	
Inhalation or Ingestion of Food Causing Obstruction	1	0.11	914	
Blow from Falling or Projected Missile	0	0.19	0	
Firearms or Explosives	0	0.08	0	
Other Vehicle Accidents	0	0.07	0	
All Other Accidents	6	3.38	177	

Table 17

Mortality Data
Underground Gold Miners in Timmins

Cause of Death	Observed	Expected	SMR	P-value
All Causes	1215	1224.42	99	
All Disease Causes	1093	1149.46	95	
Infective Diseases	29	8.36	347	2.0E-08
Silicotuberculosis	23	0.41	5639	0.0E+00
Respiratory Tuberculosis	2	3.14	64	
Other Tuberculosis	0	0.72	0	
All Other Infective Diseases	4	4.10	98	
Malignant Neoplasms	267	259.11	103	
Digestive Organs	83	90.52	92	
Stomach	35	23.72	148	1.8E-02
Intestine, Rectum	20	38.11	52	
Other Digestive	28	28.69	98	
Respiratory System	123	82.24	150	3.5E-06
Nose, Nasal Cavities etc	0	0.64	0	
Larynx	4	3.61	111	
Trachea, Bronchus, Lung	119	77.36	154	1.1E-06
Other	0	0.63	0	
Lymphatic and Haematopoietic Tissue	18	22.24	81	
Other	43	64.11	67	
Bone	0	1.06	0	
Kidney	7	5.98	117	
Bladder	3	9.98	30	
Brain	2	6.76	30	
Prostate	16	19.70	81	
Skin	0	2.81	0	
All Other	15	17.81	84	
Diseases of Circulatory System	521	686.30	76	
Ischaemic Heart Disease	361	496.96	73	
Cerebrovascular Disease	89	101.18	88	
Other	71	88.15	81	
Diseases of Respiratory System	168	81.15	207	0.0E+00
Influenza, Pneumonia, Bronchitis, Asthma	74	67.67	109	
Silicosis, Chronic Interstitial Pneumonia	82	3.88	2114	2.0E-11
Other	12	9.60	125	
All Other Disease Causes	108	114.53	94	
Accidents, Poisoning, Violence	122	74.97	163	2.8E-08
Motor Vehicle Traffic Accidents	14	21.30	66	
Water Transport Accidents	2	2.20	91	
Accidental Falls	17	10.24	166	3.3E-02
Motor Vehicle Non-Traffic Accidents	0	0.56	0	
Accidental Drowning and Submersion	2	2.45	82	
Inhalation or Ingestion of Food Causing Obstruction	2	1.58	126	
Blow from Falling or Projected Missile	30	1.55	1933	0.0E+00
Firearms or Explosives	7	0.71	980	1.0E-05
Other Vehicle Accidents	2	0.44	453	
All Other Accidents	46	33.91	136	2.8E-02

Table 18

Mortality Data
Underground Gold Miners in Kirkland Lake

Cause of Death	Observed	Expected	SMR	P-value
All Causes	472	517.07	91	
All Disease Causes	411	482.55	85	
Infective Diseases	11	3.54	311	1.1E-03
Silicotuberculosis	10	0.16	6393	0.0E+00
Respiratory Tuberculosis	0	1.33	0	
Other Tuberculosis	0	0.32	0	
All Other Infective Diseases	1	1.74	58	
Malignant Neoplasms	88	111.72	79	
Digestive Organs	24	38.51	62	
Stomach	12	9.95	121	
Intestine, Rectum	5	16.19	31	
Other Digestive	7	12.37	57	
Respiratory System	44	36.54	120	
Nose, Nasal Cavities etc	0	0.28	0	
Larynx	1	1.59	63	
Trachea, Bronchus, Lung	43	34.40	125	
Other	0	0.27	0	
Lymphatic and Haematopoietic Tissue	5	9.66	52	
Other	15	27.02	56	
Bone	0	0.46	0	
Kidney	1	2.63	38	
Bladder	2	4.07	49	
Brain	6	3.16	190	
Prostate	1	7.66	13	
Skin	0	1.23	0	
All Other	5	7.81	64	
Diseases of Circulatory System	238	285.20	83	
Ischaemic Heart Disease	168	209.74	80	
Cerebrovascular Disease	36	39.79	90	
Other	34	35.67	95	
Diseases of Respiratory System	46	33.07	139	1.9E-02
Influenza, Pneumonia, Bronchitis, Asthma	33	27.34	121	
Silicosis, Chronic Interstitial Pneumonia	10	1.61	623	7.4E-06
Other	3	4.13	73	
All Other Disease Causes	28	49.01	57	
Accidents, Poisoning, Violence	61	34.52	177	3.0E-05
Motor Vehicle Traffic Accidents	14	9.89	141	
Water Transport Accidents	4	1.07	374	2.4E-02
Accidental Falls	5	4.24	118	
Motor Vehicle Non-Traffic Accidents	0	0.27	0	
Accidental Drowning and Submersion	2	1.14	175	
Inhalation or Ingestion of Food Causing Obstruction	0	0.73	0	
Blow from Falling or Projected Missile	11	0.74	1483	4.8E-10
Firearms or Explosives	3	0.34	880	5.1E-03
Other Vehicle Accidents	1	0.21	466	
All Other Accidents	21	15.88	132	

Table 19

Mortality Data
Underground Gold Miners in Ft. William

Cause of Death	Observed	Expected	SMR	P-value
All Causes	160	168.38	95	
All Disease Causes	127	153.64	83	
Infective Diseases	4	1.13	355	2.8E-02
Silicotuberculosis	2	0.04	4818	8.4E-04
Respiratory Tuberculosis	1	0.40	247	
Other Tuberculosis	0	0.11	0	
All Other Infective Diseases	1	0.57	174	
Malignant Neoplasms	36	36.37	99	
Digestive Organs	12	12.24	98	
Stomach	6	3.08	195	
Intestine, Rectum	3	5.15	58	
Other Digestive	3	4.01	75	
Respiratory System	19	12.02	158	3.8E-02
Nose, Nasal Cavities etc	0	0.10	0	
Larynx	0	0.53	0	
Trachea, Bronchus, Lung	19	11.30	168	2.2E-02
Other	0	0.09	0	
Lymphatic and Haematopoietic Tissue	2	3.33	60	
Other	3	8.77	34	
Bone	0	0.16	0	
Kidney	1	0.89	113	
Bladder	0	1.19	0	
Brain	0	1.25	0	
Prostate	1	2.11	47	
Skin	1	0.47	212	
All Other	0	2.71	0	
Diseases of Circulatory System	67	89.29	75	
Ischaemic Heart Disease	46	66.82	69	
Cerebrovascular Disease	10	11.56	87	
Other	11	10.90	101	
Diseases of Respiratory System	13	9.93	131	
Influenza, Pneumonia, Bronchitis, Asthma	8	8.14	98	
Silicosis, Chronic Interstitial Pneumonia	5	0.48	1052	1.4E-04
Other	0	1.31	0	
All Other Disease Causes	7	16.93	41	
Accidents, Poisoning, Violence	33	14.75	224	2.9E-05
Motor Vehicle Traffic Accidents	2	4.27	47	
Water Transport Accidents	5	0.50	995	1.8E-04
Accidental Falls	1	1.48	67	
Motor Vehicle Non-Traffic Accidents	0	0.12	0	
Accidental Drowning and Submersion	1	0.49	203	
Inhalation or Ingestion of Food Causing Obstruction	0	0.30	0	
Blow from Falling or Projected Missile	6	0.34	1740	1.7E-06
Firearms or Explosives	2	0.15	1353	9.9E-03
Other Vehicle Accidents	1	0.11	931	
All Other Accidents	15	6.98	215	5.6E-03

Table 20

Mortality Data
Underground Gold Miners in Other Camps (Sudbury)

Cause of Death	Observed	Expected	SMR	P-value
All Causes	35	37.62	93	
All Disease Causes	31	35.51	87	
Infective Diseases	4	0.24	1701	1.1E-04
Silicotuberculosis	3	0.01	24144	3.2E-07
Respiratory Tuberculosis	1	0.08	1190	
Other Tuberculosis	0	0.02	0	
All Other Infective Diseases	0	0.12	0	
Malignant Neoplasms	10	7.44	134	
Digestive Organs	4	2.66	151	
Stomach	2	0.70	284	
Intestine, Rectum	0	1.14	0	
Other Digestive	2	0.82	245	
Respiratory System	3	2.15	140	
Nose, Nasal Cavities etc	0	0.02	0	
Larynx	0	0.10	0	
Trachea, Bronchus, Lung	3	2.02	149	
Other	0	0.02	0	
Lymphatic and Haematopoietic Tissue	1	0.63	158	
Other	2	2.00	100	
Bone	0	0.03	0	
Kidney	0	0.16	0	
Bladder	0	0.32	0	
Brain	0	0.17	0	
Prostate	0	0.73	0	
Skin	0	0.09	0	
All Other	2	0.51	392	
Diseases of Circulatory System	10	21.64	46	
Ischaemic Heart Disease	8	14.98	53	
Cerebrovescular Disease	1	3.65	27	
Other	1	3.02	33	
Diseases of Respiratory System	4	2.71	148	
Influenza, Pneumonia, Bronchitis, Asthma	2	2.30	87	
Silicosis, Chronic Interstitial Pneumonia	2	0.12	1725	6.2E-03
Other	0	0.29	0	
All Other Disease Causes	3	3.48	86	
Accidents, Poisoning, Violence	4	2.11	190	
Motor Vehicle Traffic Accidents	1	0.58	171	
Water Transport Accidents	1	0.06	1767	
Accidental Falls	0	0.35	0	
Motor Vehicle Non-Traffic Accidents	0	0.01	0	
Accidental Drowning and Submersion	0	0.06	0	
Inhalation or Ingestion of Food Causing Obstruction	0	0.04	0	
Blow from Falling or Projected Missile	1	0.04	2439	4.0E-02
Firearms or Explosives	0	0.02	0	
Other Vehicle Accidents	0	0.01	0	
All Other Accidents	1	0.92	109	

Table 21

Mortality Data
Underground Gold Miners in Mixed Camps

Cause of Death	Observed	Expected	SMR	P-value
All Causes	125	150.35	83	
All Disease Causes	115	142.26	81	
Infective Diseases	4	1.01	397	1.9E-02
Silicotuberculosis	3	0.05	6056	2.0E-05
Respiratory Tuberculosis	1	0.38	266	
Other Tuberculosis	0	0.09	0	
All Other Infective Diseases	0	0.49	0	
Malignant Neoplasms	27	32.39	83	
Digestive Organs	7	11.30	62	
Stomach	5	2.95	170	
Intestine, Rectum	0	4.77	0	
Other Digestive	2	3.58	56	
Respiratory System	13	10.43	125	
Nose, Nasal Cavities etc	1	0.08	1299	
Larynx	0	0.45	0	
Trachea, Bronchus, Lung	12	9.82	122	
Other	0	0.08	0	
Lymphatic and Haemotopoietic Tissue	2	2.72	74	
Other	5	7.94	63	
Bone	0	0.12	0	
Kidney	1	0.74	135	
Bladder	1	1.27	78	
Brain	1	0.78	128	
Prostate	2	2.53	79	
Skin	0	0.32	0	
All Other	0	2.17	0	
Diseases of Circulatory System	47	84.84	55	
Ischaemic Heart Disease	31	61.55	50	
Cerebrovescular Disease	9	12.54	72	
Other	7	10.75	65	
Diseases of Respiratory System	20	10.25	195	4.5E-03
Influenza, Pneumonia, Bronchitis, Asthma	6	8.49	71	
Silicosis, Chronic Interstitial Pneumonia	12	0.50	2406	1.0E-11
Other	2	1.26	158	
All Other Disease Causes	17	13.77	123	
Accidents, Poisoning, Violence	10	8.08	124	
Motor Vehicle Traffic Accidents	4	2.27	177	
Water Transport Accidents	0	0.22	0	
Accidental Falls	0	1.19	0	
Motor Vehicle Non-Traffic Accidents	0	0.06	0	
Accidental Drowning and Submersion	0	0.26	0	
Inhalation or Ingestion of Food Causing Obstruction	0	0.18	0	
Blow from Falling or Projected Missile	1	0.16	641	
Firearms or Explosives	0	0.07	0	
Other Vehicle Accidents	0	0.05	0	
All Other Accidents	5	3.64	138	

Table 22

Mortality Data
Elliot Lake Uranium Miners

Cause of Death	Observed	Expected	SMR	P-value
All Causes	999	854.26	117	3.7E-07
All Disease Causes	611	678.74	90	
Infective Diseases	3	5.64	53	
Silicotuberculosis	0	0.06	0	
Respiratory Tuberculosis	0	1.64	0	
Other Tuberculosis	1	0.58	172	
All Other Infective Diseases	2	3.36	60	
Malignant Neoplasms	187	169.70	110	
Digestive Organs	46	51.70	89	
Stomach	16	12.18	131	
Intestine, Rectum	13	21.78	60	
Other Digestive	17	17.74	96	
Respiratory System	83	53.69	155	1.2E-04
Nose, Nasal Cavities etc	0	0.58	0	
Larynx	2	2.54	79	
Trachea, Bronchus, Lung	81	50.04	162	3.5E-05
Other	0	0.52	0	
Lymphatic and Haematopoietic Tissue	22	21.19	104	
Other	36	43.13	83	
Bone	2	1.07	187	
Kidney	4	4.44	90	
Bladder	0	3.53	0	
Brain	12	9.93	121	
Prostate	4	4.47	90	
Skin	2	3.83	52	
All Other	12	15.86	76	
Diseases of Circulatory System	302	364.34	83	
Ischaemic Heart Disease	218	282.39	77	
Cerebrovascular Disease	38	37.75	101	
Other	46	44.20	104	
Diseases of Respiratory System	39	36.06	108	
Influenza, Pneumonia, Bronchitis, Asthma	26	28.85	90	
Silicosis, Chronic Interstitial Pneumonia	9	1.61	560	4.7E-05
Other	4	5.60	71	
All Other Disease Causes	80	103.00	78	
Accidents, Poisoning, Violence	388	175.52	221	0.0E+00
Motor Vehicle Traffic Accidents	113	58.16	194	0.0E+00
Water Transport Accidents	17	7.27	234	1.4E-03
Accidental Falls	34	10.42	326	5.7E-09
Motor Vehicle Non-Traffic Accidents	4	1.44	278	
Accidental Drowning and Submersion	9	6.24	144	
Inhalation or Ingestion of Food Causing Obstruction	5	2.66	188	
Blow from Falling or Projected Missile	47	4.66	1009	0.0E+00
Firearms or Explosives	13	1.90	685	1.2E-07
Other Vehicle Accidents	17	1.52	1121	0.0E+00
All Other Accidents	129	81.26	159	5.9E-08

Table 23

Mortality Data
Bancroft Uranium Miners

Cause of Death	Observed	Expected	SMR	P-value
All Causes	244	203.40	120	2.2E-03
All Disease Causes	165	167.17	99	
Infective Diseases	2	1.37	146	
Silicotuberculosis	0	0.02	0	
Respiratory Tuberculosis	1	0.43	233	
Other Tuberculosis	1	0.14	726	
All Other Infective Diseases	0	0.78	0	
Malignant Neoplasms	57	41.34	138	1.2E-02
Digestive Organs	16	12.93	124	
Stomach	4	3.10	129	
Intestine, Rectum	9	5.44	165	
Other Digestive	3	4.39	68	
Respiratory System	30	13.30	226	5.6E-05
Nose, Nasal Cavities etc	0	0.13	0	
Larynx	0	0.62	0	
Trachea, Bronchus, Lung	30	12.43	241	1.7E-05
Other	0	0.12	0	
Lymphatic and Haematopoietic Tissue	3	4.80	63	
Other	8	10.31	78	
Bone	0	0.24	0	
Kidney	2	1.06	188	
Bladder	0	0.98	0	
Brain	1	2.16	46	
Prostate	1	1.39	72	
Skin	1	0.82	122	
All Other	3	3.66	82	
Diseases of Circulatory System	78	91.71	85	
Ischaemic Heart Disease	61	70.58	86	
Cerebrovascular Disease	8	10.01	80	
Other	9	11.12	81	
Diseases of Respiratory System	10	9.35	107	
Influenza, Pneumonia, Bronchitis, Asthma	6	7.53	80	
Silicosis, Chronic Interstitial Pneumonia	1	0.43	235	
Other	3	1.39	215	
All Other Disease Causes	18	23.40	77	
Accidents, Poisoning, Violence	79	36.24	218	5.6E-10
Motor Vehicle Traffic Accidents	24	12.11	198	1.7E-03
Water Transport Accidents	2	1.51	133	
Accidental Falls	5	2.30	218	
Motor Vehicle Non-Traffic Accidents	1	0.30	329	
Accidental Drowning and Submersion	3	1.34	224	
Inhalation or Ingestion of Food Causing Obstruction	0	0.36	0	
Blow from Falling or Projected Missile	11	0.97	1138	7.1E-09
Firearms or Explosives	2	0.42	475	
Other Vehicle Accidents	3	0.28	1083	2.9E-03
All Other Accidents	28	16.46	170	5.9E-03

Table 24

Mortality Data

Eldorado Miners Who Never Mined Asbestos In Ontario

Cause of Death	Observed	Expected	SMR	P-value
All Causes	198	116.12	171	0.0E+00
All Disease Causes	132	96.93	136	1.8E-04
Infective Diseases	1	0.81	123	
Silicotuberculosis	0	0.02	0	
Respiratory Tuberculosis	1	0.27	371	
Other Tuberculosis	0	0.08	0	
All Other Infective Diseases	0	0.45	0	
Malignant Neoplasms	45	23.85	189	7.3E-05
Digestive Organs	9	7.53	120	
Stomach	4	1.83	219	
Intestine, Rectum	3	3.16	95	
Other Digestive	2	2.54	79	
Respiratory System	33	7.71	428	0.0E+00
Nose, Nasal Cavities etc	0	0.08	0	
Larynx	0	0.36	0	
Trachea, Bronchus, Lung	33	7.21	458	0.0E+00
Other	0	0.07	0	
Lymphatic and Haematopoietic Tissue	2	2.72	74	
Other	1	5.89	17	
Bone	0	0.13	0	
Kidney	0	0.62	0	
Bladder	0	0.57	0	
Brain	1	1.24	81	
Prostate	0	0.79	0	
Skin	0	0.47	0	
All Other	0	2.08	0	
Diseases of Circulatory System	58	53.45	109	
Ischaemic Heart Disease	43	41.20	104	
Cerebrovascular Disease	6	5.80	103	
Other	9	6.45	140	
Diseases of Respiratory System	8	5.36	149	
Influenza, Pneumonia, Bronchitis, Asthma	6	4.32	139	
Silicosis, Chronic Interstitial Pneumonia	1	0.25	400	
Other	1	0.78	127	
All Other Disease Causes	20	13.45	149	
Accidents, Poisoning, Violence	66	19.19	344	6.0E-11
Motor Vehicle Traffic Accidents	12	6.02	199	2.1E-02
Water Transport Accidents	2	0.78	258	
Accidental Falls	7	1.29	542	3.9E-04
Motor Vehicle Non-Traffic Accidents	1	0.16	644	
Accidental Drowning and Submersion	3	0.67	446	3.1E-02
Inhalation or Ingestion of Food Causing Obstruction	1	0.32	315	
Blow from Falling or Projected Missile	5	0.51	977	1.9E-04
Firearms or Explosives	3	0.21	1425	1.3E-03
Other Vehicle Accidents	1	0.16	639	
All Other Accidents	31	9.08	341	9.6E-09

Table 25

Mortality Data
Asbestos Miners Excluding Eldorado Miners

Cause of Death	Observed	Expected	SMR	P-value
All Causes	93	89.69	104	
All Disease Causes	63	75.59	83	
Infective Diseases	0	0.63	0	
Silicotuberculosis	0	0.01	0	
Respiratory Tuberculosis	0	0.21	0	
Other Tuberculosis	0	0.06	0	
All Other Infective Diseases	0	0.34	0	
Malignant Neoplasms	18	18.76	96	
Digestive Organs	5	5.92	84	
Stomach	1	1.42	71	
Intestine, Rectum	3	2.49	121	
Other Digestive	1	2.02	50	
Respiratory System	10	6.21	161	
Nose, Nasal Cavities etc	0	0.06	0	
Larynx	0	0.29	0	
Trachea, Bronchus, Lung	10	5.81	172	
Other	0	0.05	0	
Lymphatic and Haematopoietic Tissue	1	2.07	48	
Other	2	4.56	44	
Bone	0	0.10	0	
Kidney	0	0.49	0	
Bladder	1	0.44	230	
Brain	0	0.97	0	
Prostate	1	0.58	173	
Skin	0	0.35	0	
All Other	0	1.63	0	
Diseases of Circulatory System	35	41.76	84	
Ischaemic Heart Disease	24	32.47	74	
Cerebrovascular Disease	6	4.32	139	
Other	5	4.97	101	
Diseases of Respiratory System	4	4.09	98	
Influenza, Pneumonia, Bronchitis, Asthma	4	3.28	122	
Silicosis, Chronic Interstitial Pneumonia	0	0.19	0	
Other	0	0.62	0	
All Other Disease Causes	6	10.35	58	
Accidents, Poisoning, Violence	30	14.10	213	1.5E-04
Motor Vehicle Traffic Accidents	9	4.37	206	3.4E-02
Water Transport Accidents	1	0.57	175	
Accidental Falls	6	0.98	612	5.4E-04
Motor Vehicle Non-Traffic Accidents	0	0.12	0	
Accidental Drowning and Submersion	0	0.50	0	
Inhalation or Ingestion of Food Causing Obstruction	1	0.24	416	
Blow from Falling or Projected Missile	1	0.38	265	
Firearms or Explosives	2	0.16	1272	1.1E-02
Other Vehicle Accidents	1	0.11	905	
All Other Accidents	9	6.68	135	

Table 26

First Approximation to the Evaluation of Risk Factors for Radon Daughter Products

Camp	N	ΣWLM_{St}	ΣWLM_{Sp}	$\overline{WLM}_{St}$	$\overline{WLM}_{Sp}$	Obs	Exp	PYR	RRF_{St}	RRF_{Sp}	ARF_{St}	ARF_{Sp}
Bancroft	2,264	100,710	295,567	44.5	130.6	29	11.94	37,482	3.2×10^{-2}	1.1×10^{-2}	1.02×10^{-5}	3.49×10^{-6}
Elliot Lake	12,294	382,212	787,625	31.1	64.1	76	46.78	183,296	2.0×10^{-2}	9.7×10^{-3}	5.13×10^{-6}	2.49×10^{-6}
Bancroft & Elliot Lake	14,558	482,922	1,083,192	33.17	74.4	105	58.72	220,778	2.4×10^{-2}	1.06×10^{-2}	6.32×10^{-6}	2.82×10^{-6}

N — Number of Men with underground uranium mining exposure

ΣWLM_{St} — Total cumulative exposure using Standard Values of WLM

ΣWLM_{Sp} — Total cumulative exposure using Special Values of WLM

$\overline{WLM}_{St}$ — Mean Accumulated exposure using Standard WL Values

$\overline{WLM}_{Sp}$ — Mean Accumulated exposure using Special WL Values

Obs — Observed number of lung cancer deaths

Exp — Expected Number of lung cancer deaths

PYR — Person-Years at Risk

RRF_{St} — Relative Risk Factor (Standard) = $\dfrac{Obs-Exp}{E \times \overline{WLM}_{st}}$

RRF_{Sp} — Relative Risk Factor (Special) = $\dfrac{Obs-Exp}{E \times \overline{WLM}_{sp}}$

ARF_{St} — Absolute Risk Factor Standard = $\dfrac{Obs-Exp}{PYR \times \overline{WLM}_{St}}$

ARF_{Sp} — Absolute Risk Factor Special = $\dfrac{Obs-Exp}{PYR \times \overline{WLM}_{Sp}}$

Table 27

Observed, Expected Violent Deaths and SMR Values for Ontario Underground Miners by Ore Mined and for Colorado Uranium Miners

Ore	Obs	Exp	Obs-Exp	SMR	
Nickel-Copper	233	167.6	65.4	139	
Gold	230	134.4	95.6	171	
Iron	7	6.1	0.9	116	
Other	5	6.9	-1.9	72	
Mixed Ore	185	108.5	76.5	170	
Ontario Uranium	497	222.8	274.2	223	
Eldorado	66	19.2	46.8	344	
Asbestos	30	14.1	15.9	213	
Total	1253	679.6	573.4	184	
Colorado Uranium	155	46.8	108.2	331	(Wa81)

Table 28

Observed, Expected, Excess and SMR by Major Causes for Uranium Miners

Ham Report - This Study

	HAM[1]				THIS STUDY[2]			
Cause	Obs	Exp	Excess	SMR	Obs	Exp	Excess	SMR
All Causes	956	894.5	61.5	107	1316	1113.8	202.2	118
Violence	400	212.4	187.6	188	497	222.8	274.2	223
Cancer of Lung	81	45.1	35.9	180	119	65.8	53.2	181
Cancer of Stomach	11	12.7	-1.7	87	21	16.1	4.9	130
Diseases of Resp. System (including Silicosis)	28	32.2	-4.2	87	53*	47.8*	5.2	111*
All Non Violent	556	682.2	-126.2	82	819	890.9	-71.9	92

* Includes: Silicosis, Chronic Interstitial Pneumonia

Obs 11; Exp 2.1; Excess 8.9; SMR 514; P = 1.5×10^{-5} (one sided)

1 Up to end of 1974
2 Up to end of 1977

Table 29

Comparison of Risk Factors: Published Data and this Report

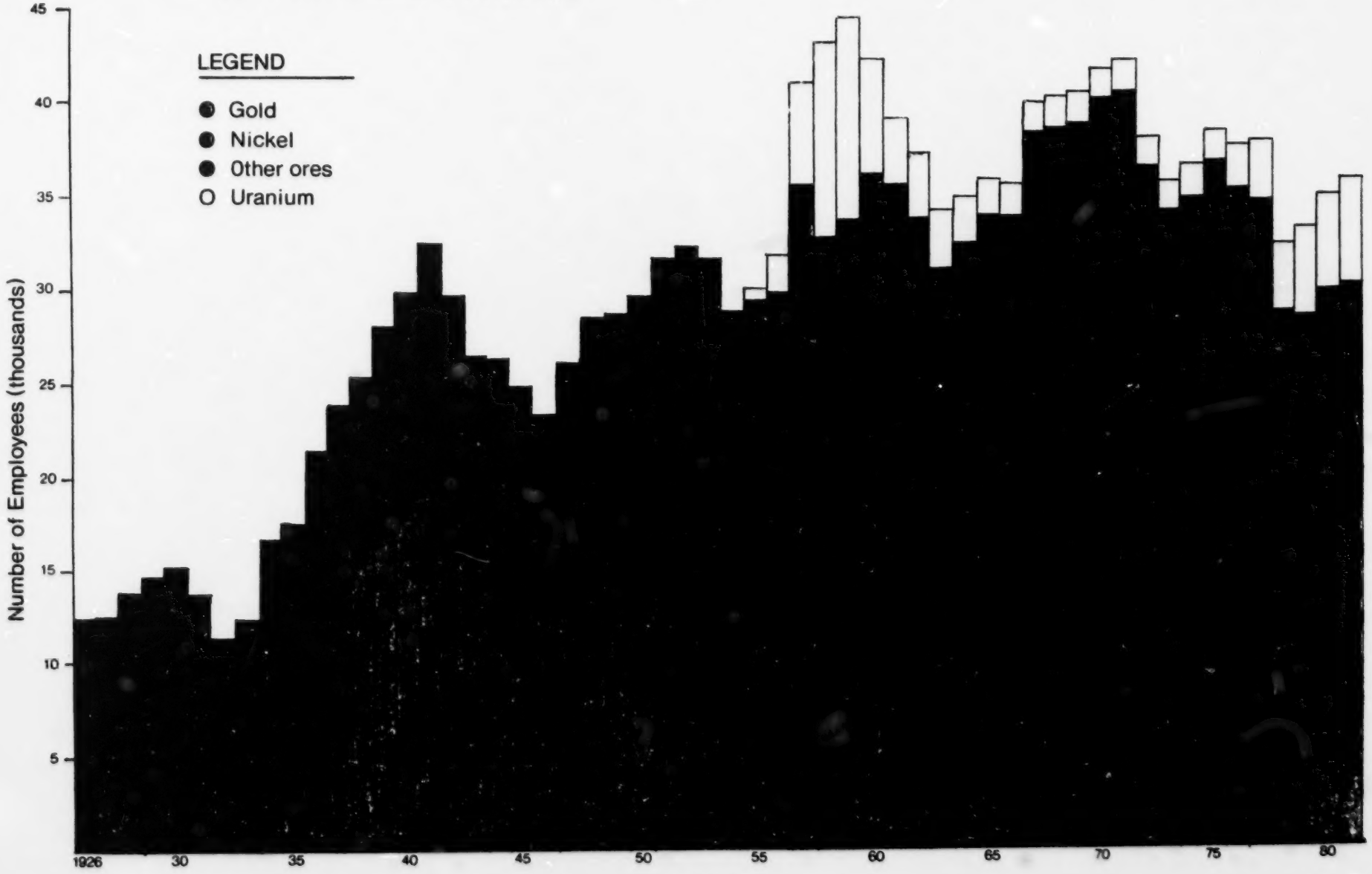
Ref.	Miners	Mean WLM	Exp.	Obs.	RRF	ARF	PYR	Remark
Ku78	Czech	279	7.5	37.2	1.4×10^{-2}	10.6×10^{-6}	56,995	Exp and Obs are given per 10^4 PYR. No correction for latency.
Be80	US	1180	25.24	159	4.5×10^{-3}	3.5×10^{-6}	32,196	Lung cancer deaths and PYR for less than 10 years after starting mining are excluded.
This report	Ontario using:							
	Std.WLM	33	58.7	105	2.4×10^{-2}	6.3×10^{-6}		
	Spec.WLM	74	58.7	105	1.1×10^{-2}	2.8×10^{-6}	220,778	
	Average	53.5	58.7	105	1.5×10^{-2}	3.9×10^{-6}		

For meanings of headings of columns see Table 27

APPENDIX B

FIGURES

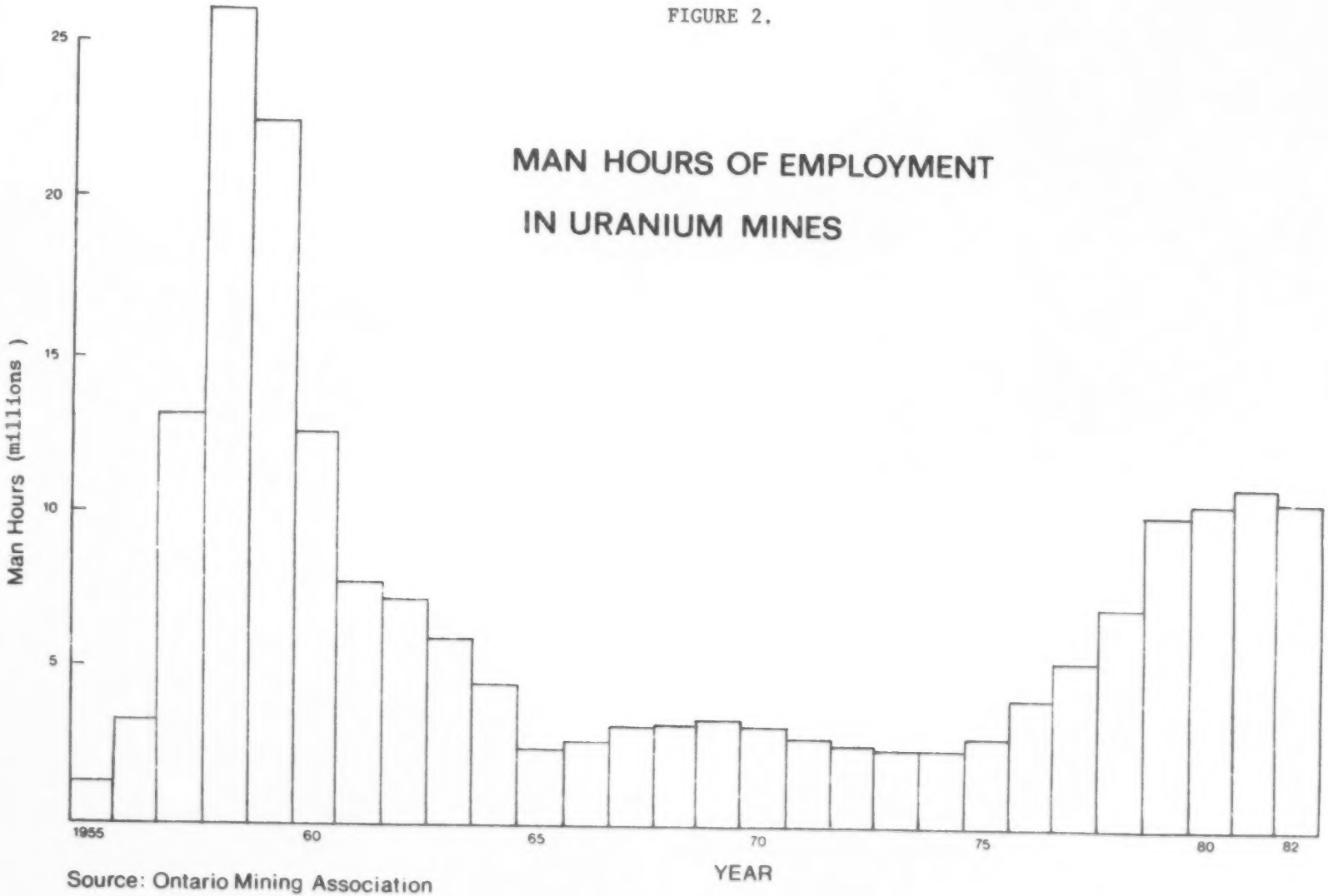
EMPLOYMENT IN MINES



Source: Ontario Mining Association

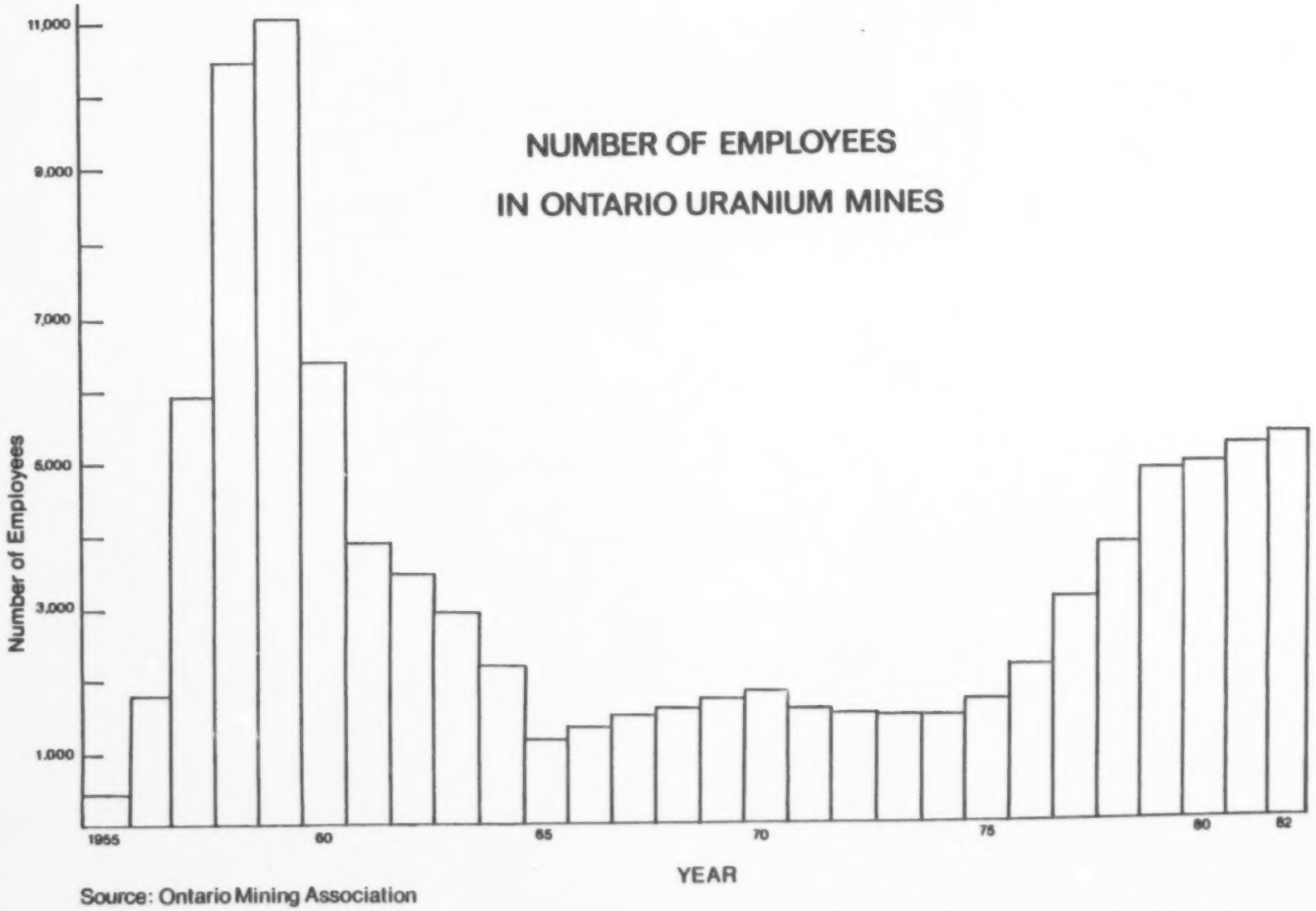
(1983)

FIGURE 2.



Source: Ontario Mining Association

FIGURE 3



Source: Ontario Mining Association

Fig 4: YEAR OF BIRTH BY ORE MINED

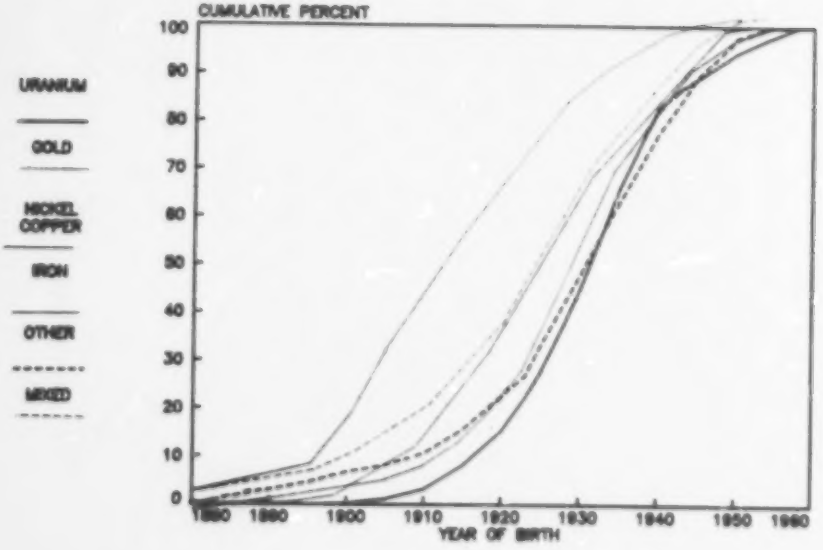


Fig 5: YEAR OF FIRST ONTARIO MINING BY ORE MINED

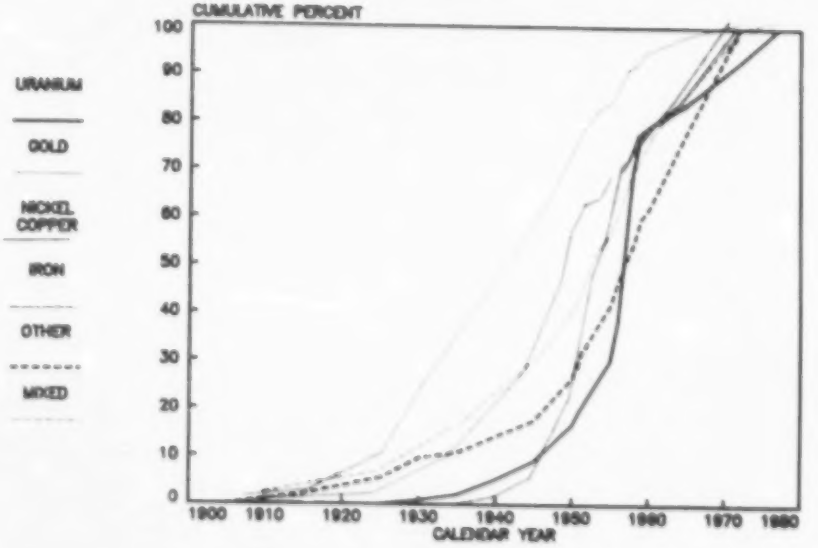


Fig 6: YEARS OF MINING IN ONTARIO BY ORE MINED

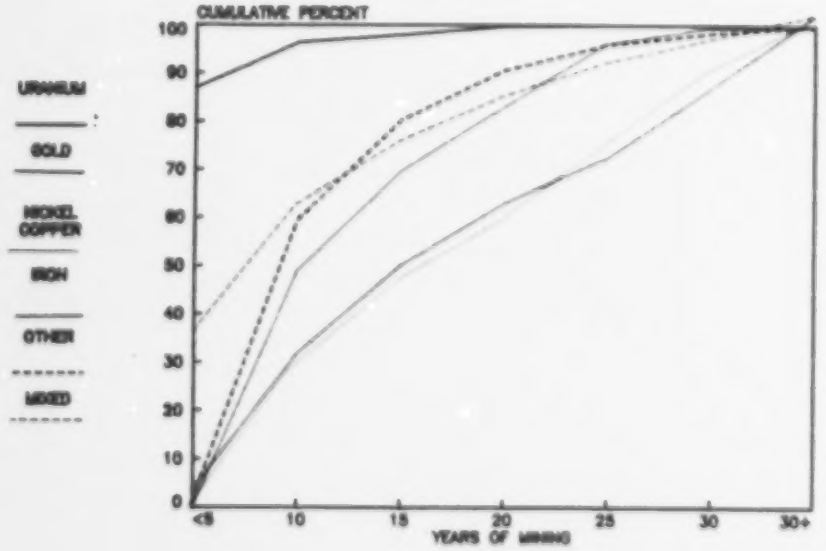


Fig 7: YEAR OF ENTRY INTO STUDY BY ORE MINED

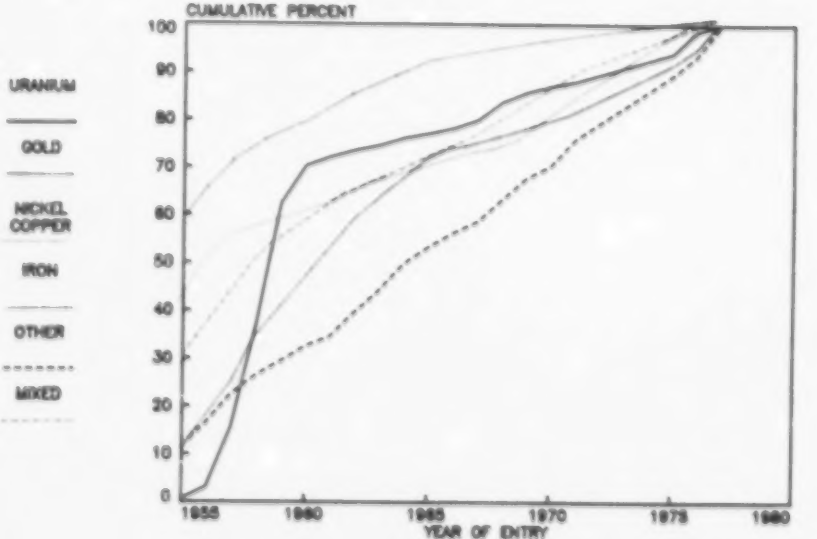


Fig 8: PERSON-YEARS AT RISK
BY AGE AND ORE MINED

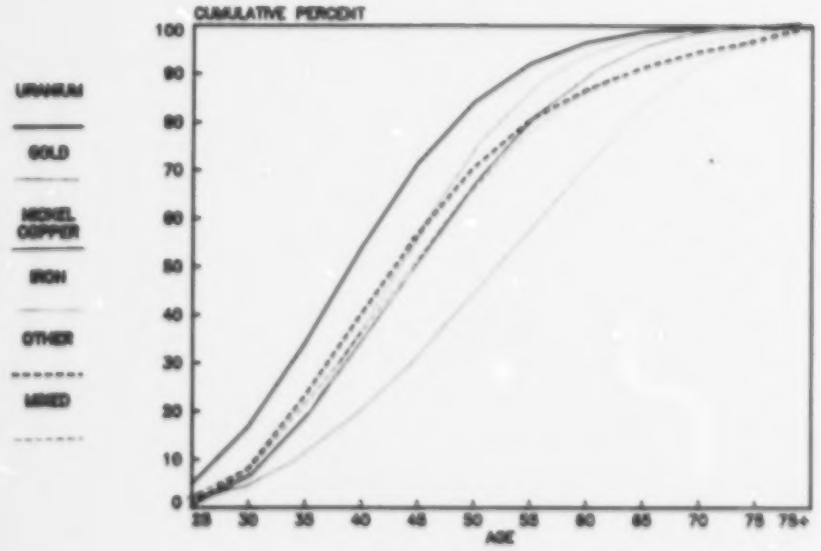


Fig 9: LUNG CANCER DEATHS 'EXPECTED'
IN URANIUM MINERS' STUDY POPULATION

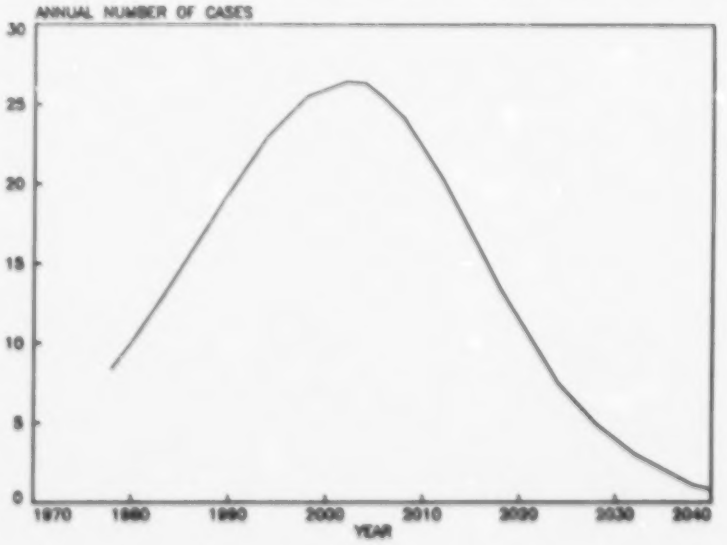


Fig 10: YEAR OF BIRTH FOR GOLD MINERS BY CAMP

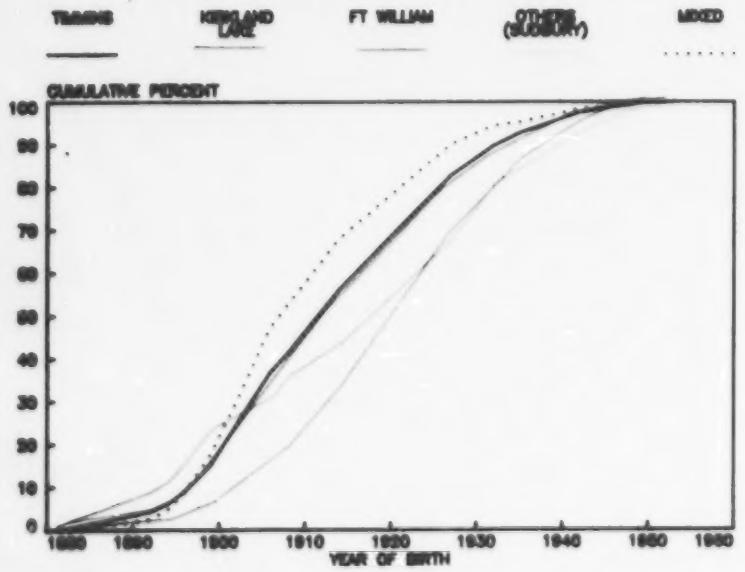


Fig 11: YEAR OF FIRST ONTARIO MINING
FOR GOLD MINERS BY CAMP

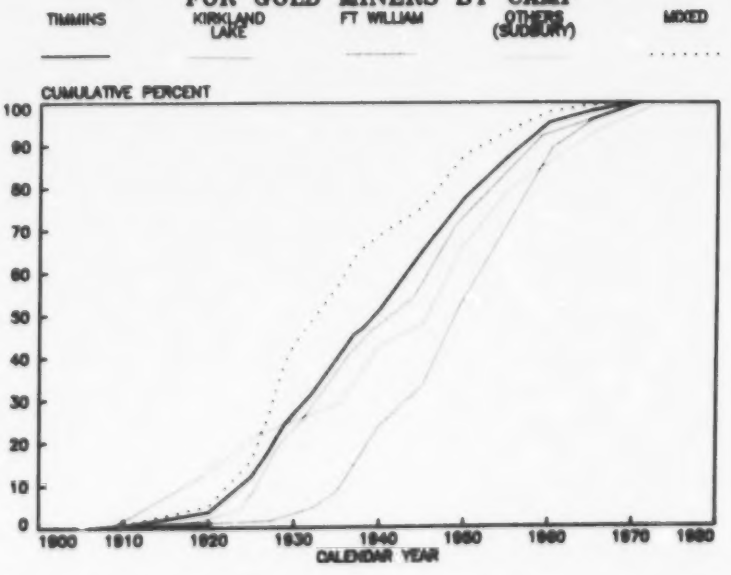


Fig 12: YEARS OF GOLD MINING BY CAMP

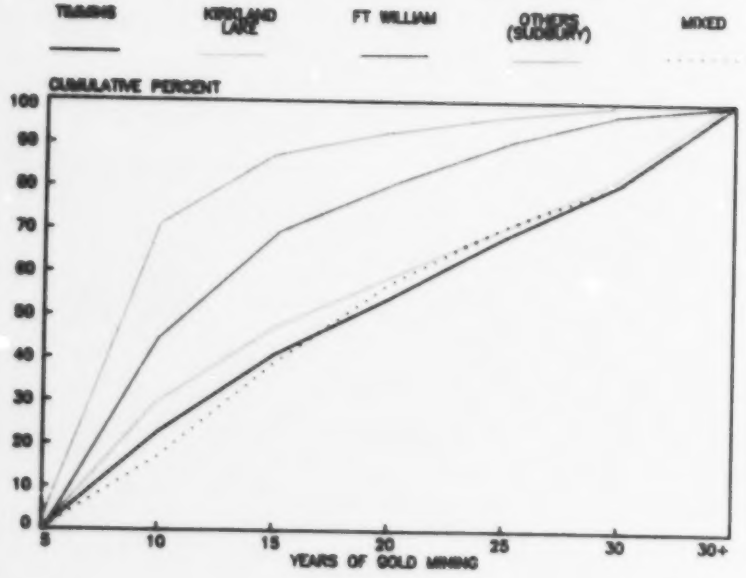


Fig 13: YEAR OF ENTRY INTO STUDY FOR GOLD MINERS BY CAMP

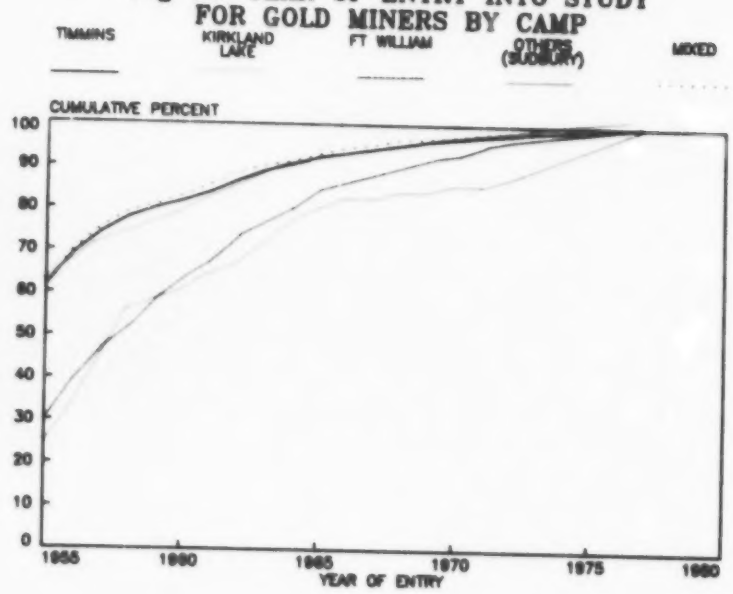


Fig 14: PERSON-YEARS AT RISK IN GOLD MINERS BY AGE AND CAMP

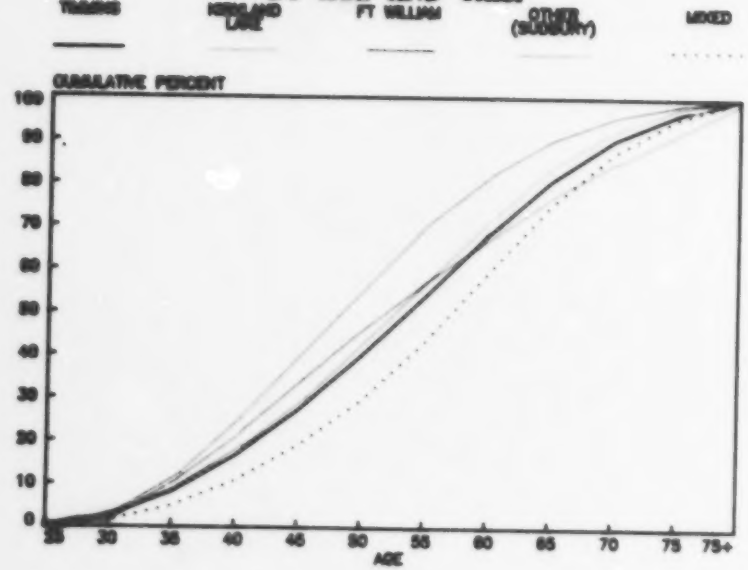


Fig 15: YEAR OF BIRTH FOR URANIUM MINERS BY CAMP

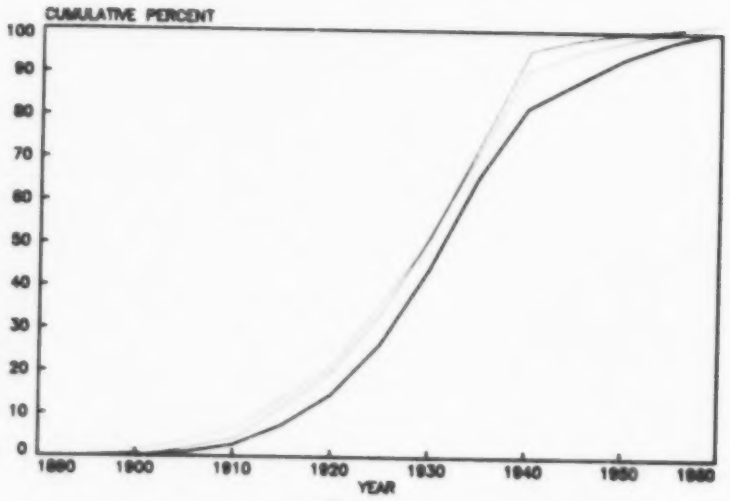


Fig 16: YEAR OF FIRST ONTARIO MINING FOR URANIUM MINERS BY CAMP

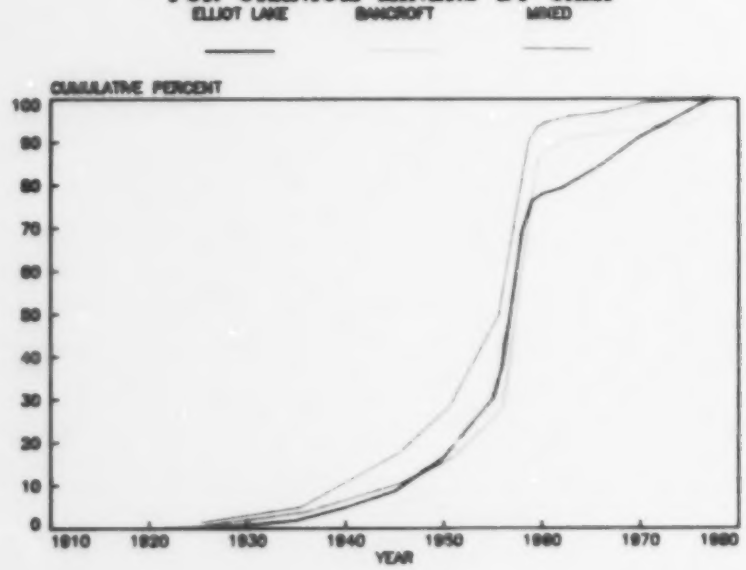


Fig 17: YEARS OF MINING FOR URANIUM MINERS BY CAMP

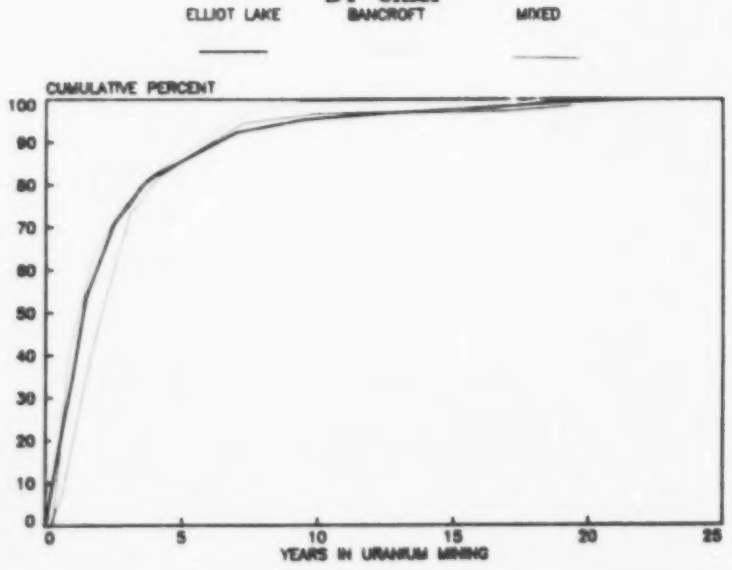


Fig 18: YEAR OF ENTRY INTO STUDY FOR URANIUM MINERS BY CAMP

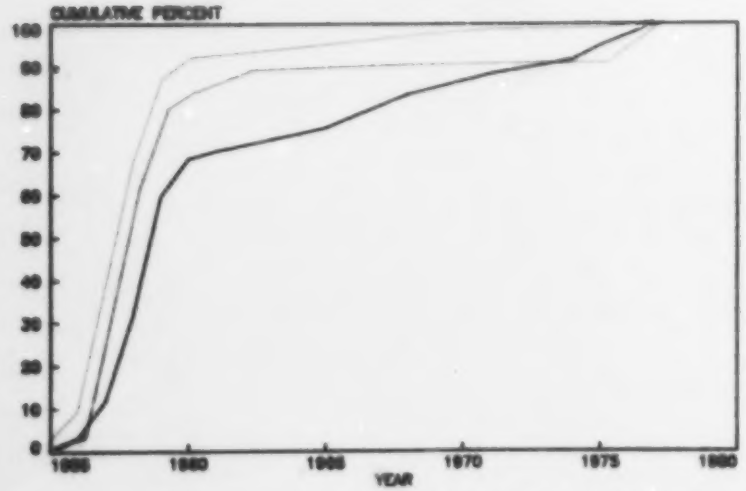
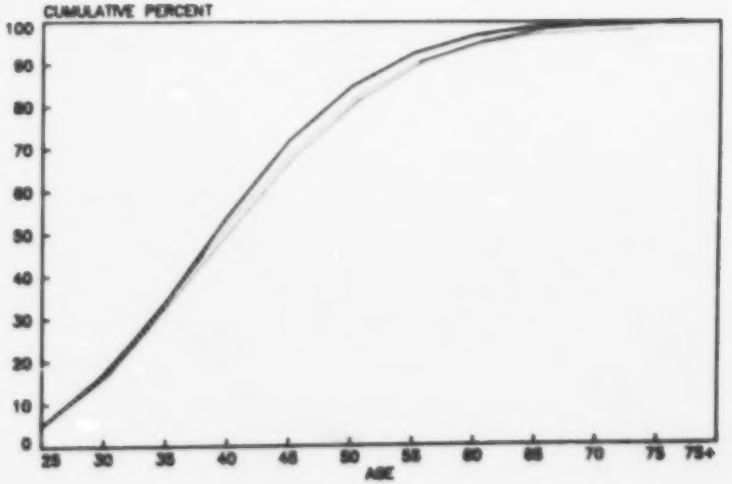


Fig 19: PERSON-YEARS AT RISK BY AGE AND CAMP FOR URANIUM MINERS



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POOR

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